National Aeronautics and Space Administration

NASA'S BEST STUDENTS

BEGINNING ENGINEERING, SCIENCE, AND TECHNOLOGY

An Educator's Guide to the Engineering Design Process
Grades 6-8

www.nasa.gov

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PREFACE

The NASA BEST Activities Guide has been developed by at team from the NASA Goddard Space Flight Center's Office of Education in support of NASA's Exploration Systems Mission Directorate (ESMD). ESMD develops capabilities and supporting research and technology that will make human and robotic exploration possible. It also makes sure that our astronaut explorers are safe, healthy, and can perform their work during long-duration space exploration. ESMD does this by developing robotic precursor missions, human transportation elements, and life-support systems. Ultimately, this Directorate of NASA serves as a stepping stone for the future exploration of Mars and other destinations

The NASA BEST Activities Guides were designed to teach students the **Engineering Design Process**. Our team created three guides to accommodate three grade groups: K-2, 3-5 and 6-8. All follow the same set of activities and teach students about humans' endeavor to return to the Moon. Specifically, how we investigate the Moon remotely, the modes of transportation to and on the Moon, and how humans will live and work on the Moon.

The Engineering Design Process is a series of steps engineers use to guide them in problem solving. Engineers must ask a question, imagine a solution, plan a design, create that model, experiment and test that model, then take time to improve the original – all steps that are crucial to mission success at NASA. What makes this guide different from others is: (1) there are no specific instructions or "recipes" for building the items; and (2) there are no given drawings. The emphasis is for students to understand that engineers must "imagine and plan" before they begin to build and experiment. To successfully complete the NASA BEST Activities, students must **draw their ideas first** before constructing.

Many of the activities have been adapted from others, and then aligned with the theme of efforts to return to the Moon with a focus on using the Engineering Design Process. Each activity features objectives, a list of materials, educator information, procedures, and student worksheets. When appropriate, the guide provides images, charts, and graphics for the activities. All activities are intended for **students to work in teams**. It is recommended that each team consist of 3 or 4 students. The activities can be used to supplement curricula during the school day or as activities in after-school clubs; as a set or individually. This guide of activities was also designed to keep material costs to a reasonable limit, using items often already found in the classroom or from home. Furthermore, all activities correlate to national science, mathematics, technology, and engineering standard(s). A list of national standards is included at the end of this guide.

We appreciate your interest in this product. Remember, *let the students have fun!*

- Susan Hoban, Project Manager

ACKNOWLEDGEMENTS

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MATERIALS

*Below is a **suggested** list of materials needed to complete all activities in this guide for a group of 24-32 students (~8 teams). In addition, for your convenience, a NASA BEST Kit is available for purchase from Science Kit/Boreal Laboratories (www.sciencekit.com/NASABEST/), which supports ~30 students.*

STANDARD MEASURING TOOLS

Digital scale (1)
Graduated cylinder (1)
Meter sticks (1 per team)
Measuring tape (1)
Rulers (1 per team)
Stopwatches (1 per team)
Thermometers (2 per team)

MATERIALS FOR ACTIVITIES AND GENERAL BUILDING SUPPLIES

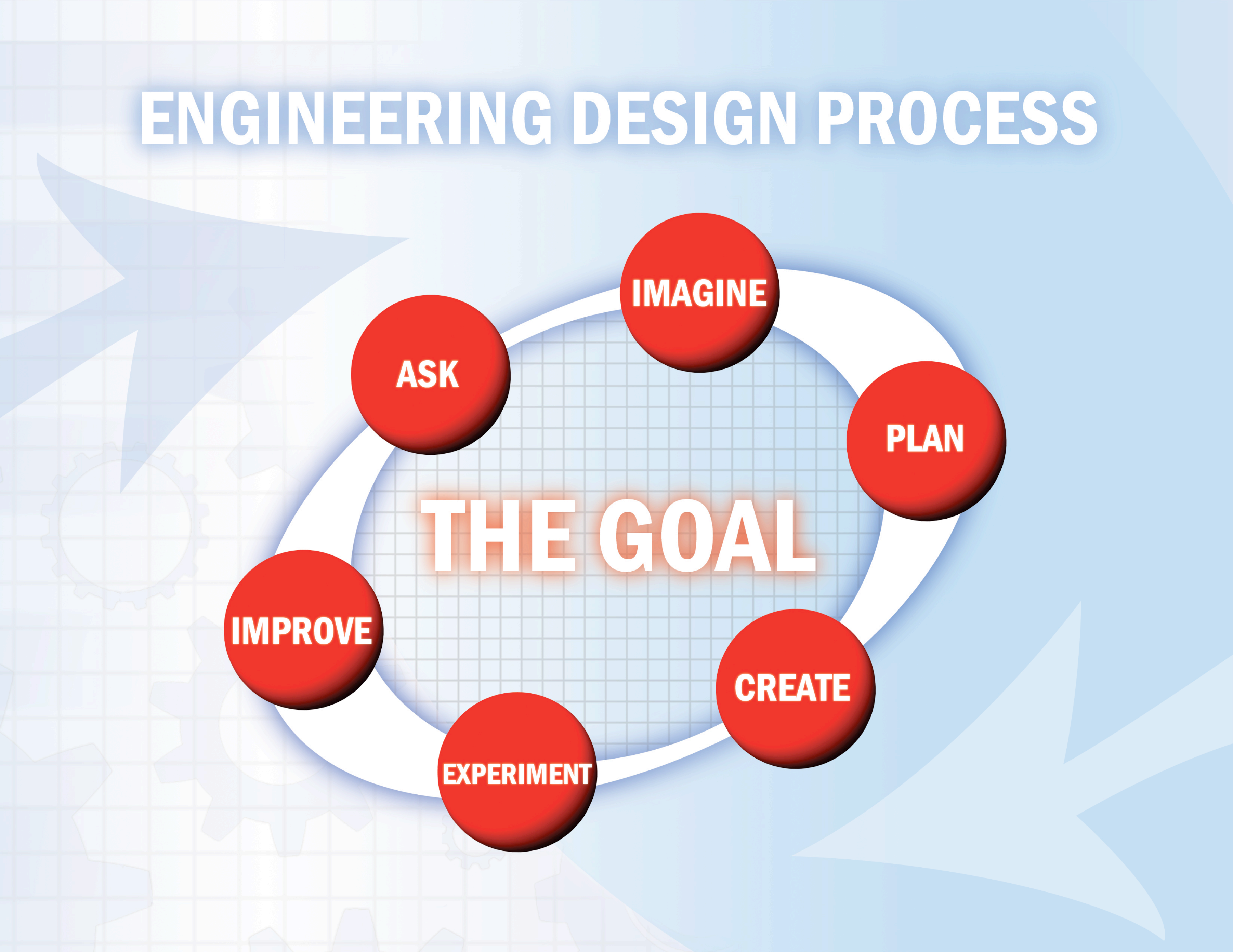
aluminum foil
balloons, assorted
bamboo skewers
binder clips, assorted
blindfolds (1 per team)
bubble wrap
buttons or beads, assorted (~10 per team)
cardboard
card stock
cardboard boxes (1 per team)
c-clamps (at least two)
cheesecloth
clothespins (with springs)
cloth swatch, i.e. quilting square
coffee filters
colored pencils and crayons
cotton balls
empty paper towel tubes
empty toilet paper tubes
fishing line, ~20 lb. test, 5 m
film canisters
glow sticks (2)
glue sticks
index cards
mailing tube, 4” diameter or oatmeal canister
mini foil pie plates (1 per team)
modeling clay
paper bags
paper clips, assorted
pennies (at least 10 per team)
pipe cleaners
plastic cups
plastic eggs (1 per team)
plastic people (i.e. Lego® or Playmobil®)[1]
plastic wrap
popsicle sticks and/or tongue depressors
rubber bands, assorted
scissors
shoe boxes or similar size boxes
staplers and staples
stirrer sticks
straws
string
tape: masking, electrical, transparent and duct tapes
wheels: i.e. model car wheels (plastic or wood), empty thread spools, or rotelle pasta (4-6 per team)

1 If toy plastic people are unavailable, encourage students to make their own “astronauts”.

TABLE OF CONTENTS

ACTIVITIES

APPENDIX


ENGINEERING DESIGN PROCESS
ASK
IMAGINE
PLAN
CREATE
EXPERIMENT
IMPROVE
THE GOAL

BUILD A SATELLITE TO ORBIT THE MOON

OBJECTIVE

To demonstrate an understanding of the Engineering Design Process while utilizing each stage to successfully complete a team challenge.

CHALLENGE

To design and build a satellite that meets specific size and mass constraints. It must carry a combination of cameras, gravity probes, and heat sensors to investigate the Moon's surface. The satellite will need to pass a 1-meter Drop Test without any parts falling off of it.

PROCESS SKILLS

Measuring, calculating, designing, evaluating

MATERIALS

General building supplies

Bag of various sized buttons

1 Mailing tube, oatmeal canister or other container (used as a size constraint)

STUDENT PAGES

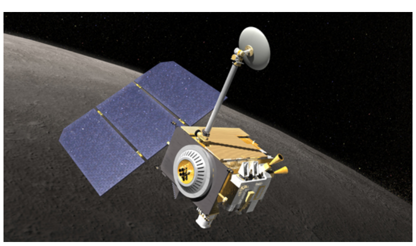
Design Challenge

Ask, Imagine and Plan

Experiment and Record

Quality Assurance Form

Fun with Engineering at Home



MOTIVATE

- Spend a few minutes asking students if they know what engineers do, then show the NASA's BEST Students video titled, "What is Engineering":

  svs.gsfc.nasa.gov/goto?10515
- Using the *Engineering Design Process (EDP)* graphic on the previous page, discuss the EDP with your students:
  - **Ask** a question about the goal.
  - **Imagine** a possible solution.
  - **Plan out** a design and draw your ideas.
  - **Create** and construct a working model.
  - **Experiment** and test that model.
  - **Improve** and try to revise that model.

SET THE STAGE: ASK, IMAGINE, PLAN

- Share the *Design Challenge* orally with the students (see next page).
- Have students brainstorm ideas, solve the given problems and then create a drawing of their satellite. All drawings should be approved before building begins.

CREATE

- Distribute materials for students to build their satellites based on their designs and specifications.
- Ask teams to double check mathematical calculations, designs and models. Visit each team to make sure their model can fit within the size specification of the cylinder or box you are using.

EXPERIMENT

- Have students test their satellites by dropping them from a 1-meter height and to record their observations.
- Emphasize the importance of experimenting with a new design and receiving feedback for optimizing success in engineering.

IMPROVE

- Have students evaluate their satellite and rework their designs if needed.

CHALLENGE CLOSURE

Engage the students in a discussion with the following questions:

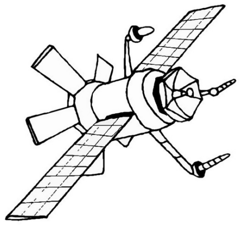
- *List two things you learned about what engineers do through building your satellite today.*
- *What was the greatest difficulty your team had today while trying to complete the satellite challenge?*
- *How did your team solve this problem?*

PREVIEWING NEXT SESSION

Ask teams to bring back their satellite models for use at the next session. You may want to store them in the classroom or have one of the club facilitators be responsible for their safe return.

DESIGN CHALLENGE

NASA's Lunar Exploration Missions



NASA's lunar exploration missions will collect scientific data to help scientists and engineers better understand the Moon's features and environment. These missions will ultimately help NASA determine the best locations for future human exploration and lunar bases.

Satellite Instruments

The information gathered by lunar exploration missions will add to information collected during earlier missions. Some of these missions gathered data that caused scientists to have more questions — questions they hope to solve with new instruments on new satellites. For example, NASA has recently sent a satellite to look for water ice on the Moon. Thus, that satellite carried instruments (sometimes called "detectors" or "sensors") to look for the ice. Other instruments will help collect data to make exact maps of the Moon's surface and make careful measurements of the radiation falling on the lunar surface for the safety of future lunar explorers.

Teamwork is Important

The different instruments are designed, tested, and assembled by different teams of engineers and scientists. The separate teams must work together to ensure instruments are the right mass, fit correctly, and make proper measurements. Working together is an important skill for *everyone* to practice.

The Challenge: *Your mission is to build a model of a lunar exploration satellite with the general building supplies provided. Each team should create their own satellite. Use different shape/sizes of buttons or beads to represent the various instruments. The design constraints are:*

1. *The total mass of the instruments, detectors, probes, sensors and solar cells can be no greater than **60 kilograms** (see Satellite Instrument Data Table, p.4).*
    a. *The satellite cannot be launched if the mass of instruments, detectors, probes and solar cells exceeds a total of 60 kilograms, so choose your instruments carefully.*

2. *The entire satellite must* ***fit within the __________ (i.e. mailing tube, oatmeal canister)****. This item is a size constraint. The satellite is not to be stored in this or launched from this item.*

3. *At least two instruments must "deploy" (unfold or pop out) when the satellite is launched. These instruments must be mounted on a part that moves.*

4. *The satellite must withstand a 1-meter Drop Test without any pieces falling off.*

ASK, IMAGINE AND PLAN

What questions do you have about today's challenge?

Use the data in this table to determine which instruments, and how many of those instruments, to include on your satellite.

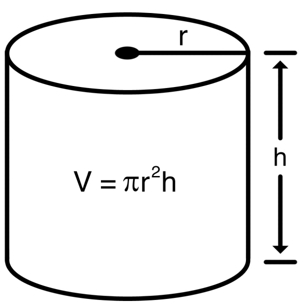
Satellite Instrument Data Table

Detectors or Instruments	Use	Mass (kg)	Number of solar cells needed to power
Camera	takes pictures	30	1
Gravity Probe	measures gravity	20	2
Heat Sensor	measures temperature	10	3
Solar Cell	collects energy from the Sun to power an instrument, detector, sensor, or probe	1	n/a

Our Team's Satellite Instrument Data Table

Instrument	Mass
	kg
	kg
	kg
Total Number of Solar Cells:	kg
Total mass of instrument package	kg
Volume of Payload Container (see hint below)	cm^3
Does your satellite fit within size constraints?	

HINT – How to calculate the volume of a cylinder:



1. Find the radius (r) of the circle found at the top and bottom of the cylinder. The radius is half of the measurement of the diameter of the circle.
2. Square the radius value and multiply it by π (pi).
3. Determine the height (h) of your cylinder and multiply it by the value found in step #2.

Use this space for your volume calculations.

How will the instruments on your design deploy when the satellite is launched?

____

Draw two views of the satellite with its instruments you intend to build:

View 1

View 2

Approved By ________________

EXPERIMENT AND RECORD

Pair up with another team to do a Drop Test. Each team should evaluate another team's drop by completing the Quality Assurance Form (next page). Drop your satellite from a height of 1 meter. If needed, use a meter stick to measure the height.

What happened when you completed the 1-meter Drop Test?

____

____

Did any pieces fall off? If yes, which ones?

____

____

What kinds of changes are needed to make to your satellite stronger?

____

____

Draw your satellite with these new modifications.

What is the total mass of your instruments and solar cells after making these new changes?

____

QUALITY ASSURANCE FORM

Each team is to review another team's design and model, then answer the following questions.

Name of team reviewed: ______________________________

	YES	NO
Does the satellite fit within specified size constraint?		
Did the satellite withstand the Drop Test?		
Will the instruments deploy upon launch?		

Total mass of the instruments is: ______________ grams

List the specific strengths of the design.

List the specific weaknesses of the design:

How would you improve the design?

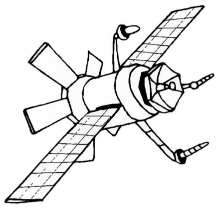
Inspected by: ___________________________________

____

____

____

FUN WITH ENGINEERING AT HOME



Today you designed and built a satellite model to orbit the Moon. You used the same process that engineers use when they build something. You had to **ASK**: what is the challenge? Then you thought, talked and **IMAGINED** a solution to the challenge. You **PLANNED** with your group and **CREATED** a model satellite. Finally, you **EXPERIMENTED** or tested your model by having other groups look at it and give you feedback. Last, you went back to your work stations and tried to **IMPROVE** the satellite. These are the same 6 steps engineers use when they try to solve a problem or a challenge.

While at home, see what you can learn about satellites — how they work, what they are used for, and how scientists and engineers get them up into orbit. You may even want to see if you can find out what kind of sensors, instruments and probes the satellites orbiting the Earth carry.

You can find this information in books, magazines or on the Internet. Here are some Internet links you may want to use:

World Book at NASA: Artificial Satellites

www.nasa.gov/worldbook

The World Almanac for Kids Science: Artificial Satellites

www.worldalmanacforkids.com

NASA Space Place

spaceplace.nasa.gov/en/kids/quiz_show/ep001/

LAUNCH YOUR SATELLITE

OBJECTIVE

To demonstrate an understanding of Engineering Design Process while utilizing each stage to successfully complete a team challenge.

CHALLENGE

To design a balloon rocket to launch the satellite that was built in the last activity. The goal is to get the satellite to go as far as possible.

PROCESS SKILLS

Observing, communicating, measuring, collecting data, inferring, predicting, making models.

MATERIALS

Satellite model from previous activity

General building supplies

Rulers or meter sticks

Binder clips or clothes pins

Balloons (several per group)

Straws

5-meter fishing line set-up strung between two tables

STUDENT PAGES

Design Challenge

Ask, Imagine and Plan

Experiment and Record

Quality Assurance Form

Fun with Engineering at Home

PRE-ACTIVITY SETUP

The fishing line apparatus should be at least 5 meters in length. Clamp or tie one end at table or chair height and stretch the line across the space to another table/chair at the same level. Holding the free end of the line taut for each trial enables easy restringing of the successive balloon rockets. The line must be very taut for best results. Shoot the rockets toward the tied end. Two fishing line set-ups should be sufficient for most clubs. *Note: Use clips or clothes pins to hold filled balloon shut before launch. If the opening in the balloons tends to stick, try putting a little hand lotion inside the opening.*

MOTIVATE

- Show the video of a recent rocket launch, titled, "Liftoff…To the Moon!"

  lunar.gsfc.nasa.gov/launch.html

SET THE STAGE: ASK, IMAGINE, PLAN

- Share the *Design Challenge* with the students and ask students to retrieve their satellites from last session.
- Demonstrate how a balloon rocket works by sending a balloon connected to a straw up the fishing line. Do not model how best to attach the satellite or how best to power the rocket, other than releasing the air by using your fingers.
- Ask the students, "How can we use this setup to launch your satellite?" Remind students that one end of the line is the launch pad and the other end is the Moon.
- Have students take the time to imagine a solution for a balloon rocket design and then draw their ideas. All drawings should be approved before building begins

CREATE

- Challenge the teams to build their rockets based on their plans. In addition, teams will need to design a system to attach their satellites to the launch setup. Remind students to keep within specifications.

EXPERIMENT

- Send teams to their assigned launch sites to test their rockets, completing the data table as they conduct each trial launch.

IMPROVE

- After the first set of trials, allow teams to make adjustments to their rockets.
- Teams re-launch satellites and record their data.
- Teams discuss how far their rocket traveled and which combination of variables gave the best results.

CHALLENGE CLOSURE

Engage the students in the following questions:

- *What was the greatest challenge for your team today?*
- *Why is the balloon forced along the string?*
- *How did changing the straw length/number of balloons affect how far the rocket travelled on the fishing line?*

PREVIEWING NEXT SESSION

Ask teams to think about how humans navigate robotic rovers on a distant planet or moon. How are they programmed? How do the rovers receive messages from a team on Earth?

DESIGN CHALLENGE

3, 2, 1…We have lift-off!

NASA launches several rockets each year. There are actually several launch facilities around the United States. You probably know of the launch pad at Kennedy Space Center in Florida, but did you know there is a launch facility at Vandenberg Air Force Base in California, one at Wallops Flight Facility in Virginia, and another at White Sands Missile Range in New Mexico? A rocket is just the launch vehicle that carries a **payload** into space. A payload is the load, or package or set of instruments, that needs to be delivered to a destination. When you watched the video for this session, you saw an Atlas V rocket carry a payload, the LRO and LCROSS satellites, to a destination: an orbit around the Moon.

The Challenge: Your mission is to design and build a launch vehicle to send a payload to the Moon. Your payload is the satellite you built at the last session. The launch vehicle is a balloon rocket assembly. Your team must also determine how to attach your satellite to the balloon assembly and then launch it down a fishing wire. The design constraints are:

1. *Between trials, you must change the length of the straw on your rocket.*
2. *Once you have selected an appropriate straw length, select one other rocket element for your design and modify only that element during your remaining trials. The rocket elements are:*
    a. *number of balloons*
    b. *type of balloon(s): long or round (if time and materials permit)*

ASK, IMAGINE AND PLAN

What questions do you have about today's challenge?

How will you choose what lengths to make the straw?

____

Predict how the effect of the length of the straw on the launch assembly might change the launch distance of your satellite.

____

____

Explain how you think changing the straw length changes how far the rocket travels?

____

____

What is the next rocket element (or variable) that you plan to test? How are you going to test it?

____

____

Predict what will happen when you make these changes.

____

____

Draw your balloon rocket assembly and include your satellite:

Approved By _______________

EXPERIMENT AND RECORD

Experiment 1. Select the number and shape of balloons you want to use. This is your control. Only modify the length of straw for each trial.

	Trial 1	Trial 2	Trial 3
Straw Length (cm)			
Distance traveled (cm)			

Number of balloons?	Balloon shape?

Experiment 2. Change the number of balloons for each trial, but keep the straw length and shape of balloons constant.

	Trial 1	Trial 2	Trial 3
Number of Balloons			
Distance traveled (cm)			

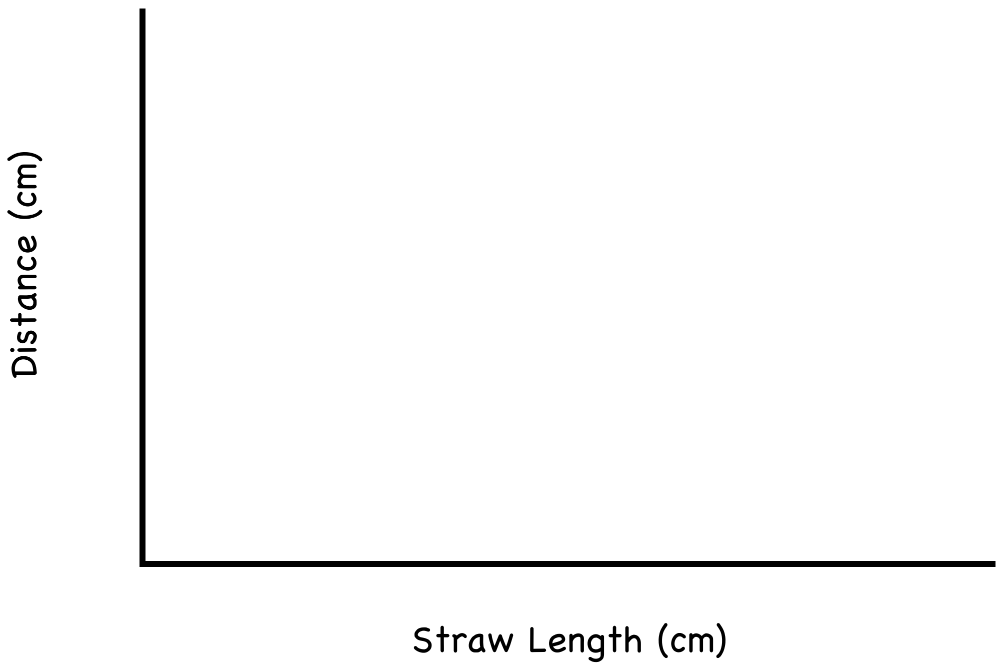
Length of straw?	Balloon shape?

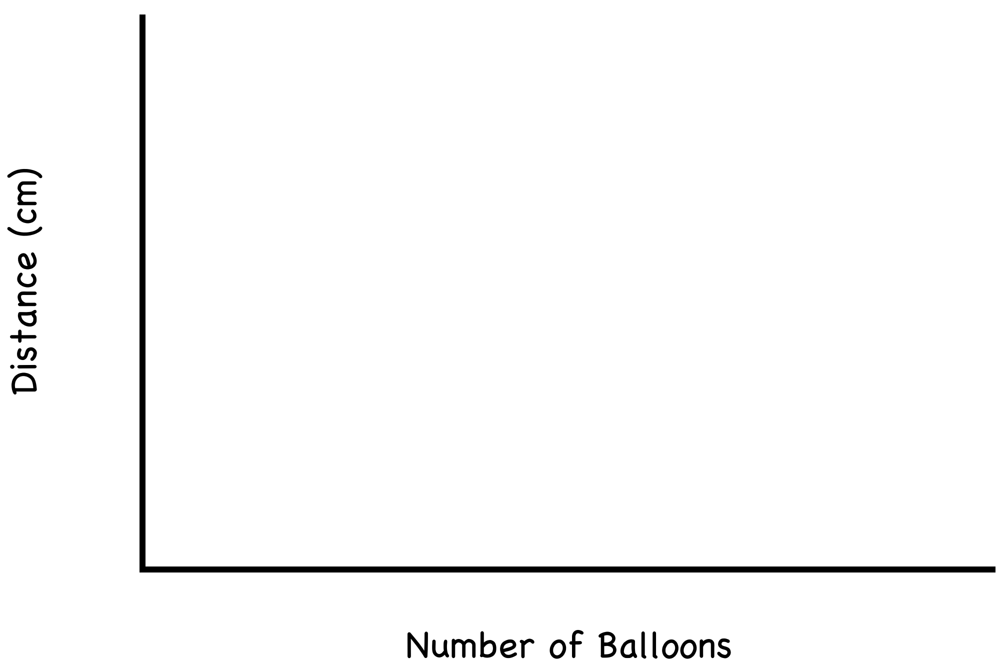
Experiment 3 (if time and materials permit). Select different shapes of balloons for each trial but keep the straw length and number of balloons constant.

	Trial 1	Trial 2	Trial 3
Shape of balloon(s)			
Distance traveled (cm)			

Length of straw?	Number of balloons?

Plot the data from your tables on the graphs below.





QUALITY ASSURANCE FORM

Each team is to review another team's design and model, then answer the following questions.

Name of team reviewed: ______________________________

What was the farthest distance the rocket travelled?

___________________cm

What design components were on the rocket that made it travel this far?

Straw Length?	
Number of Balloons?	
Balloon Shape?	

List specific strengths of the design.

List specific weaknesses of the design:

How would you improve the design?

Inspected by: ___________________________________

____

____

____

FUN WITH ENGINEERING AT HOME

Today you designed and built a balloon rocket to send your lunar satellite to the Moon. By creating a model using simple classroom supplies, you still used the same process that engineers use when they build a rocket assembly to put satellites in space. While at home, see what you can learn about rockets: how they work, what they are used for, and what types of fuel are used to get them into space.

American rocketry was pioneered by Dr. Robert Goddard. NASA's Goddard Space Flight Center is named after him. For further reading about Dr. Goddard:

www.nasa.gov/centers/goddard/about/dr_goddard.html

To read about the Ares V rocket, check out this link:

www.nasa.gov/mission_pages/constellation/ares/rocket_science.html

NASA's Marshall Space Flight Center studies propulsion and manages the Michoud Facility in New Orleans.

www.nasa.gov/centers/marshall/about/index.html

CHALLENGE: What kinds of rockets carry satellites into space? Are these the same kind of rockets that carry astronauts into space? Ask your family members to help you investigate!

PREPARE FOR A MISSION

OBJECTIVE

Students will demonstrate an understanding of the Engineering Design Process while utilizing each stage to successfully complete a team challenge.

CHALLENGE

To execute a mini-simulation of a robotic mission with a goal to command a human-robot through a set course to retrieve a piece of lunar ice.

PROCESS SKILLS

Mapping, communication, measuring, graphing, logical thinking

MATERIALS

Rulers or meter sticks

Blindfolds

"prize" as lunar ice sample

STUDENT PAGES

Ask, Imagine and Plan

Experiment and Record

Quality Assurance Form

Fun with Engineering at Home

PRE ACTIVITY SETUP

Set up a small obstacle course with a few chairs, waste paper baskets, and/or a table. The course does not have to be too complicated, but set it up so students will have to take at least one right turn and one left turn. Also, give the students enough obstacles so there is more than one path to take to the "finish". An area of about 25 square meters is recommended.

Please note: This activity will require two 60-90 minute sessions to complete. Make sure to set up the obstacle course exactly the same for both sessions. Also, student acting as the robot will need to be blindfolded for this activity. Please take time to discuss with your students about assisting or "spotting" their blindfolded peer.

MOTIVATE

- Many of NASA's missions are conducted by robots. While some robots can make decisions based on data received from sensors, humans must program the robots - we tell robots what to do and how to execute their missions.

SET THE STAGE: ASK, IMAGINE, PLAN

- Share the *Design Challenge* with the students.
- First, have students draw their chosen course on the map. They must include at least one right turn and one left turn. Map should be approved before proceeding to next step.
- Let students practice commands to use with their robot. These commands are simple words, plus a number for steps taken.

CREATE

- Students will identify the robot's route through the lunar landing site and count the number of steps needed for each command to calibrate the distance the robot travels on a given command. From this, a command sequence for their robot can be created, then tested on the planned route of their maps.

EXPERIMENT

- Student teams must navigate the lunar landing site, using the command sequence each team designed. Have students cut out the commands into strips of paper and designate one student per team to deliver each command. Designate another team member to run a stopwatch. Position the robots at the start and have the teams sitting or standing aside from the obstacle course. The students designated to deliver commands are to deliver one command at a time – one student walks to the robot, delivers one command, then returns to the team. Robot performs the command. The next student then walks to the robot and delivers the command, returns, etc. Only one command is delivered at a time to represent one line of code sent over a radio signal. The rest of the team cannot deliver another command until they have determined if the robot has successfully executed that command. Have each team record how much time it takes to successfully complete the task when the robot picks up the "lunar ice".

CHALLENGE CLOSURE

Engage students in the following questions:

- *Did each team pick the same route or were there several routes to get to the lunar ice? Which route worked the best?*
- *Why did you have to deliver each command separately? How does it relate to communicating with robots in space?*

PREVIEWING NEXT SESSION

Ask teams to think about how a spacecraft might land on the Moon safely. Ask them to think about why it does not make sense to use a parachute on the Moon. Answer: There is no air on the Moon to fill up the parachute.

DESIGN CHALLENGE

The Discovery Mission

Every NASA mission has several parts leading to its success. When leading a remote mission on another planet or moon, NASA scientists and engineers must plan every step of the mission carefully. When using robots or rovers, each mission team must calibrate and program these machines to accomplish the mission objective, such as to travel to certain locations on that planet or moon.

The Challenge: Your team has been chosen to operate a robotic Discovery Mission on the surface of the Moon. You will be given a specific starting location, and your robot must move through a lunar landscape to the location of the "lunar ice" without bumping into any "lunar boulders" or other obstacles. To successfully complete the Discovery Mission, your robot must retrieve a piece of "lunar ice" for analysis.

Before your robot begins to move on the lunar surface, you will have to complete the following *activities:*

1. ***Designate your robot*** *- One student per team must be the robot. The robot is the person who actually walks through the course, blindfolded, following the instructions of her/his team. Select a name for your robot.*

2. ***Map the landing site*** *– Using the enclosed chart, create a map of the landing site, making sure to accurately measure the distances between objects.*

3. ***Learn to communicate with your robot*** *– Each team must develop commands for your robot. You will practice these commands until you and the robot are comfortable with them. These will be the commands that you will give the robot to travel through the path you have drawn on the map.*

4. ***Calibrate your robot*** *– After practicing a set of commands with your robot, you must measure the distance the robot travels with each step or command sequence.*

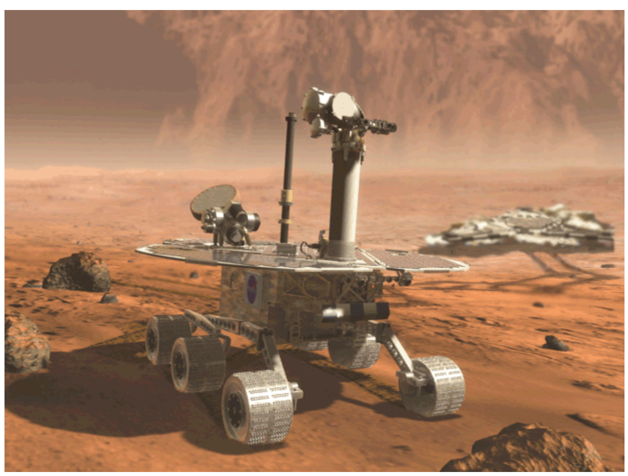
5. ***Program the robot*** *– Use the commands you developed to successfully direct the robot through the predetermined route based on the calibrations you made of how far your robot travels with each step.*

ASK, IMAGINE AND PLAN

What questions do you have about today's challenge?

STEP 1 – Designate a team member to be your robot and create a name for your robot.

STEP 2 – Map the landing site. Produce a map of the lunar "landing site" to plan your robot's route. Observe the site, measure the distance between objects and accurately replicate their positions in the grid on the next page. Think about the units you need to use for your measurement and what strategy you will use to make your measurement. For example, can you use floor tiles?



Create your map below. Each square represents a unit of ________________.

STEP 3 – Communicate with your robot

When you program a robot, you must use simple words and be specific in your directions. If you want your robot to go forward, how many steps should the robot go? Practice the words below with your robot and see if your robot follows the commands correctly.

Sample Command for Robot	Action by robot
MOVE FORWARD TWO STEPS	Walk forward two steps.
MOVE BACKWARD ONE STEP	Walk backward one step.
TURN RIGHT 90°	Turn to the right
TURN LEFT 180°	Turn to the left to face the opposite direction.
BEND AND GRAB	Bend at the waist and pick up the lunar ice sample

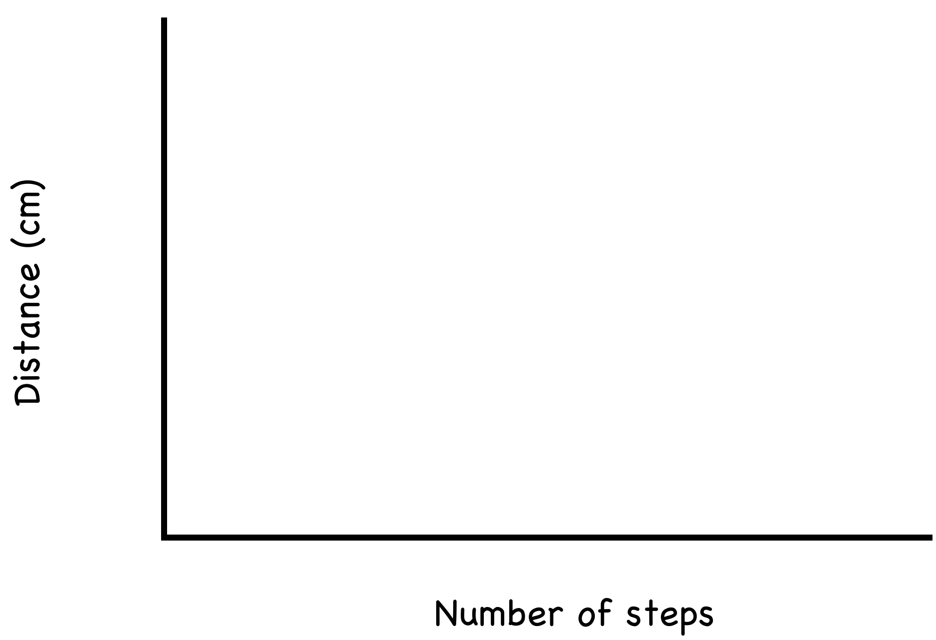
As a team, decide on the type of commands you want to use to program your robot. You may use the ones suggested above and create your own, but once those vocabulary terms are designated in this list, you may not use any other new commands once your robot has landed in the starting position.

Additional commands to use:

STEP 4 – Calibrate your robot

Practice delivering forward commands to your blindfolded robot. Measure the distance traveled by the robot for each command. Repeat three times and calculate a mean. Graph your results.

	Trial 1	Trial 2	Trial 3	Mean
Forward 1 step	cm	cm	cm	cm
Forward 2 steps	cm	cm	cm	cm
Forward 4 steps	cm	cm	cm	cm
Forward 6 steps	cm	cm	cm	cm
Forward 8 steps	cm	cm	cm	cm



Can you predict how far your robot will travel in 10 steps? ____________ cm

STEP 5 – Program your robot

Review the map with your team and plan a route for your robot. Based upon the calibration results, create commands for your robot to match your route. Write down one command for each slot below.

Command Sequence

1.	11.
2.	12.
3.	13.
4.	14.
5.	15.
6.	16.
7.	17.
8.	18.
9.	19.
10.	20.

EXPERIMENT AND RECORD

Execute the Discovery Mission!

It is time to let your Robot explore the Moon! You planned your route and practiced your commands. Now complete the mission. Take the complete command sequence your team designed and cut each command out of the page as separate strips of paper. Designate two team members to deliver the commands to the Robot and divide those strips of paper among them. Another team member, using a stopwatch, should time how long it takes for the Robot to reach the Lunar ice sample and successfully complete the mission. Don't forget that the Robot must be blindfolded! If the Robot makes a mistake or runs into an obstacle, the team must stop the mission, return to mission control to reconvene and discuss the issue, then modify the command sequence and resend the radio signal (strip of paper with command) to the Robot.

Record each team's time in the table below to compare how long the mission took for each team! Afterwards, pair up with another team to complete your Quality Assurance assessment.

Discovery Mission Data Table

Team Name	Time (seconds)
1.	
2.	
3.	
4.	
5.	

QUALITY ASSURANCE FORM

Each team is to observe another team's Discovery Mission, then answer the following questions.

Name of Robot and team reviewed: ___________________________

Did the team deliver commands to the Robot one sequence at a time? (only one radio signal per command sequence)

Did the Robot execute commands correctly?

Did the Robot reach its destination with the original set of commands?

If not, how many times did the team have to reprogram the Robot to reach the lunar sample?

____

List 2 or 3 recommendations you have for this team:

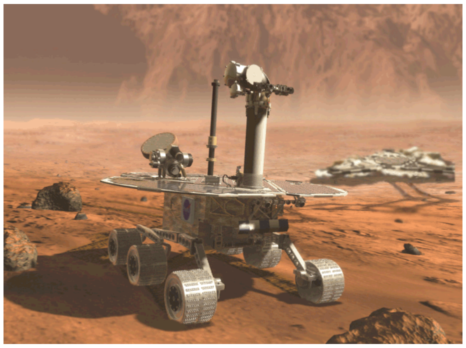
Inspected by: ____________________________________

____

____

____

FUN WITH ENGINEERING AT HOME



Today you conducted a simulated, robotic Discovery Mission. You practiced many of the very same activities that NASA scientists and engineers do when planning and executing a remote exploration mission, such as mapping, calibrating, communicating and programming. Learn more about the efforts to develop a Lunar robotic rover prototype to further study the Moon:

www.frc.ri.cmu.edu/projects/lri/scarab/index.html

CHALLENGE: Recruit your family members to try a Discovery Mission at home! Rearrange some furniture or household items to set up the Lunar Landing Site. Demonstrate to everyone the steps needed to accomplish the mission – ask your teacher for new worksheets from the activity to give to your family to use. If you have a big family or are doing this with lots of friends, you could break into teams and race to the end. Just be careful and considerate of your robot, who is blindfolded. Be creative with an item to collect as a Lunar ice sample, and have fun!

YOU BE THE TEACHER! Explain to your family why it is important to map the site prior to sending a rover to retrieve a sample. Emphasize why engineers must repeat an exercise before getting repeatable results.

DESIGN A LUNAR BUGGY

OBJECTIVE

To demonstrate an understanding of Engineering Design Process while utilizing each stage to successfully complete a team challenge.

CHALLENGE

To design and build a model of a Lunar Buggy that will carry equipment and astronauts on the surface of the Moon and to determine the best slope of ramp for the rover to travel the farthest distance.

PROCESS SKILLS

Measuring, calculating, designing, evaluating

MATERIALS

General building supplies

Meter stick

Digital scale

Small plastic people (i.e. Lego®)

Plastic eggs

Pennies or washers ("cargo")

Wheels

Something to use as a ramp

(preferably a flat surface that would enable the buggy to roll for 25 cm or more)

STUDENT PAGES

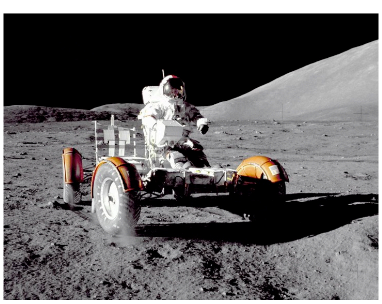
Design Challenge

Ask, Imagine and Plan

Experiment and Record

Quality Assurance Form

Fun with Engineering at Home



MOTIVATE

- Show the video about the Apollo 15 Lunar Buggy on the Moon:

  starchild.gsfc.nasa.gov/Videos/StarChild/space/rover2.avi

- Ask students to pay particular attention to the comments made about the difficulties in driving on the lunar surface.

SET THE STAGE: ASK, IMAGINE, PLAN

- Share the *Design Challenge* with the students
- Remind students to imagine solutions and draw their ideas first. All drawings should be approved before building.

CREATE

- Challenge the teams to build their Lunar Buggies based on their designs. Remind them to keep within specifications.
- While each group is working, designate one or two students to create a ramp with a slope of 1 to 3 in which all groups will use to roll their buggies and record observations.

EXPERIMENT

- Students must test their designs down the ramp and record the distance travelled for each trial.
- Students should try a "Goldilocks" experiment and test various slopes to give the best distance travelled with their Lunar Buggy. What slope is too little? What slope is too large? What slope is just right? Have the students record their results.

IMPROVE

- Students *improve* their Lunar Buggy models based on results of the *experiment* phase.

CHALLENGE CLOSURE

Engage the students in the following questions:

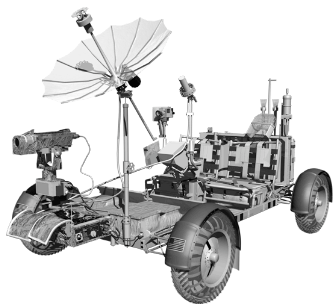
- *Did the cargo mass make a difference in your Buggy's performance?*
- *How did the slope of the ramp affect your Buggy's performance?*

PREVIEWING NEXT SESSION

Ask teams to bring back their Lunar Buggy models for use in next session's challenge. You may want to store them in the classroom or have the facilitator be responsible for their safe return next session.

Ask teams to think about potential landing pods during the next session. Tell students they will be building the landing pod out of the materials that have been available to them. The pod will be dropped from as high as possible (out a second story window, off a tall ladder, or from the top of a staircase).

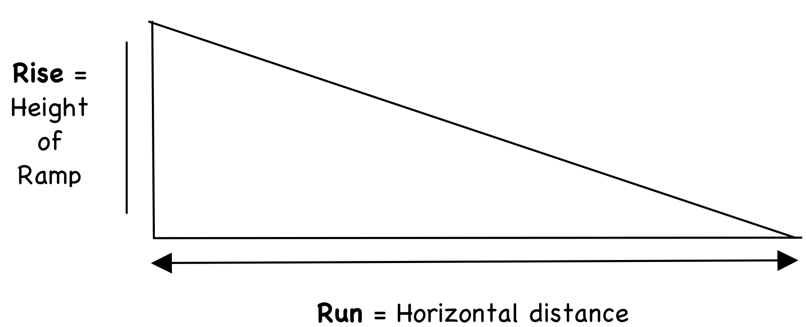
Let's Go For A Ride!



During the first set of activities, you have spent some time thinking about how to get to the Moon. Now you need to think about landing on the Moon, and how to deliver cargo to the Moon. Astronauts will need a mode of transportation in order to investigate different areas of the Moon. During the Apollo missions, astronauts drove a Lunar Buggy several kilometers away from their spacecraft. Today you get to be the engineers designing a new Lunar Buggy that can perform functions the Apollo Lunar Buggy could not. Your challenge is to build a model of a Lunar Buggy that astronauts will eventually use to carry *astronauts and cargo* on the Moon.

The Challenge: *Each team must design and build a Lunar Buggy with the following constraints:*

1. *The Lunar Buggy must carry one plastic egg snugly. The egg may not be taped or glued into place. (The egg represents the cargo hold.)*
2. *The Lunar Buggy must be able to roll with the cargo hold carrying 10 pennies (or washers).*
3. *The Lunar Buggy must have room for two "astronauts". You may use plastic people provided to you or make your own. Your astronauts may not be taped or glued into place.*
4. *The Lunar Buggy must roll on its own down a ramp with a rise-over-run of 1-over-3 for a distance of approximately 100 cm in a straight line beyond the end of the ramp.*
5. *The Lunar Buggy must be able to hold cargo and astronauts in place and intact as the Buggy rolls down the ramp.*



ASK, IMAGINE AND PLAN

What questions do you have about today's challenge?

What parts do you need in order to make your buggy roll?

____

____

What will hold the egg in place?

____

What will hold the astronauts in place?

____

What is the height of the ramp (rise) and the horizontal distance (run) for this Challenge?

Rise	cm
Run	cm

Draw your Lunar Buggy and provide a close-up view of your wheel and axle design. Make sure to label all the parts of your design.

Buggy design
Wheel and axle design ***Approved By ______________***

EXPERIMENT AND RECORD

After you have created your model Lunar Buggy based on your drawings, test your vehicle on the ramp and record how far the Buggy travels beyond the ramp. Indicate the changes your team makes to the design to get the best performance for your Lunar Buggy. Remember, the challenge is to have your Lunar Buggy travel at least 100 cm beyond the ramp in a straight line!

Lunar Buggy Distance and Modification Data Table

Trial	Distance Traveled (cm)	Modification to make to design
1		
2		
3		
4		

Use the space below to draw the updated plans for your newly designed Buggy.

Now that you tested your Buggy at a constant slope of 1 over 3, what slope do you think would make your Lunar Buggy travel the farthest? Write your hypothesis below in a complete sentence.

____

____

____

Set up your ramp with different slopes and record how far your Lunar Buggy travels beyond the end of the ramp each time.

Lunar Buggy and Ramp Data Table

Trial	Rise-over Run	Distance Traveled (cm)
1	1 over 3	
2		
3		
4		
5		
6		

At what slope did the buggy no longer roll, but slid or fall off the ramp?

____

Science Pop Question!

What force is acting on the Lunar Buggy to get it to roll down the ramp?

____

QUALITY ASSURANCE FORM

Each team is to review another team's design and model, then answer the following questions.

Name of team reviewed: ______________________________

How far does the Buggy roll on a ramp with slope of 1-over-3?

_______________ cm

Did the egg or astronauts fall out from the Buggy with slope of 1-over-3?

Using a digital scale, measure the mass of the Lunar Buggy (without the penny cargo).

_______________ grams

Do you think mass has an impact on the Buggy's performance? Explain your answer.

List specific strengths of the design.

List specific weaknesses of the design:

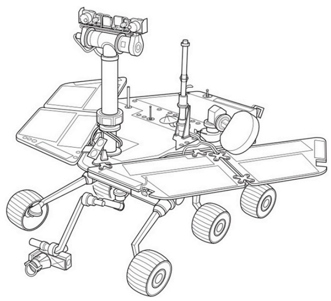
Inspected by: ___________________________________

____

____

____

FUN WITH ENGINEERING AT HOME



Today you designed and built a Lunar Buggy model to transport astronauts and cargo on the Moon. Before humans can travel to other planets, they first must send robotic rovers to these remote locations to investigate the surface of that planet. While at home, see what you can learn about the robotic rovers that NASA has already built and used to investigate other planets. For example, you can learn about the challenges in building the Mars Exploration Rovers from this website:

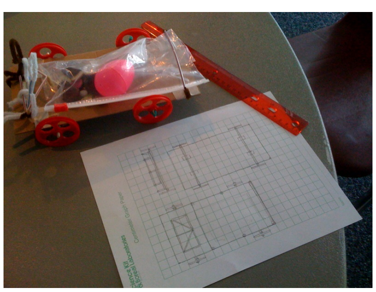
marsrover.nasa.gov/gallery/video/challenges.html

Here are some questions to discuss with your family members:

1. *What Apollo mission used a Lunar Buggy and how was it delivered to the Moon's surface for that mission?*
2. *Using the imagery from the Lunar Reconnaissance Orbiter, can you locate any remnants of the Apollo missions?*

   www.nasa.gov/mission_pages/LRO/multimedia/index.html

3. *What is the most important consideration when designing a vehicle that will carry astronauts and cargo?*
4. *What kind of cargo might a vehicle need to carry on the Moon for future missions?*



YOU BE THE TEACHER!

Explain to your family why the PLAN step in the Engineering Design Process is so important. Use your latest experiment with the Lunar Buggy as an example.

DESIGN A LANDING POD

OBJECTIVE

To demonstrate an understanding of Engineering Design Process while utilizing each stage to successfully complete a team challenge.

CHALLENGE

To design and build a Landing Pod for the model Lunar Buggy that was built in the previous session.

PROCESS SKILLS

Measuring, calculating, designing, evaluating.

MATERIALS

Lunar Buggy with egg cargo

General building supplies

Meter stick

Balloons

Bubble wrap and/or packaging material

Cardboard and/or shoeboxes

STUDENT PAGES

Design Challenge

Ask, Imagine and Plan

Experiment and Record

Quality Assurance Form

Fun with Engineering at Home

Please note: *This activity may require two 60-90 minute sessions to complete.*

MOTIVATE

- Show the video titled "Entry, Decent, and Landing (EDL)."

  marsrovers.nasa.gov/gallery/video/challenges.html

- Ask students to pay particular attention to the ways NASA slowed the rovers down as they entered the atmosphere. Note the difference between the Martian atmosphere and that of the Moon. Explain that with no atmosphere on the Moon, a parachute will not work!

SET THE STAGE: ASK, IMAGINE, PLAN

- Share the *Design Challenge* with the students.
- Remind students to imagine a solution and draw their ideas. All drawings should be approved before building.

CREATE

- Challenge the teams to build their Landing Pod based on their designs. Remind them the Lunar Buggy must be secured inside the Pod but cannot be taped or glued in place.

EXPERIMENT

- Each team must complete three trial drops and record observations.
- The actual "landing" is simulated by the facilitator. Suggestions: Drop Landing Pods safely out of a second story window, from a landing of a stairwell or from the top of a ladder. (Safety note: follow the manufacturer's recommendation when using a ladder.) Just be sure the students know ahead of time what to expect.
- Open each Landing Pod after it comes to rest and check Buggy is upright.
- Using the same ramp as last session with a slope of 1-over-3, place the Landing Pod at the top of the ramp and let the Lunar Buggy roll out. (It might require a little push.)
- The students should measure the distance the Buggy rolls beyond the ramp and check to see if the egg stayed closed.

IMPROVE

- Students *improve* their Landing Pods based on results of the three trial drops and roll tests.

CHALLENGE CLOSURE

Engage the students with the following questions:

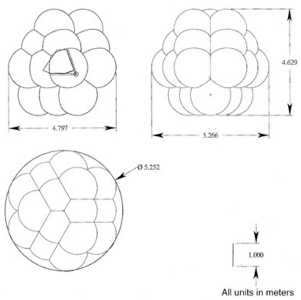
- *Which materials worked best to protect the Lunar Buggy?*
- *If you knew you ahead of time that your Buggy had to survive a landing, would you have made any changes to your design?*

PREVIEWING NEXT SESSION

Soon NASA will send the next generation of explorers to Mars or other destinations in the solar system aboard a new *Crew Exploration Vehicle* (CEV). The next session will have teams design and build a CEV that will carry two - 2 cm sized passengers safely and will fit within a certain size limitation.

DESIGN CHALLENGE

Fragile Cargo! Handle with Care!



Now that you have designed a Lunar Buggy that will transport astronauts around the lunar surface, you need to think about safely delivering this vehicle to the Moon. When NASA sent its two robotic rovers, **Spirit** and **Opportunity,** to Mars, they landed on Mars in a very interesting fashion. They fell out of the Martian sky, slowed down by a parachute and then bounced on the surface until they came to a stop! How did they do that? The rovers were inside a landing pod made of AIR BAGS! But the Martian atmosphere and surface is very different from the Moon, so to repeat this on the Moon would require several design modifications.

The Challenge: Each team must design and build a Landing Pod that will safely deliver your Lunar Buggy to the Moon's surface. The Landing Pod must meet the following constraints:

1. *The Landing Pod must safely deliver your Lunar Buggy to the surface from a height given by the teacher.*
2. *The Landing Pod must land RIGHT-SIDE up and the Lunar Buggy roll out in the correct orientation.*
3. *Materials of the Landing Pod must be reusable for other missions on the lunar surface. If a balloon pops or tape folds over on itself, those items are no longer reusable.*
4. *The Landing Pod must have a hatch or door for release of the Lunar Buggy, and should then roll out with no more than a nudge onto the ramp. Therefore, the Lunar Buggy cannot be taped or glued inside the Landing Pod.*
5. *The Lunar Buggy should not suffer any damage from the lunar landing and still be able to roll down a ramp with a slope of 1-over-3 and 100 cm beyond the ramp.*

ASK, IMAGINE AND PLAN

What questions do you have about today's challenge?

From what height will you drop Landing Pod for testing?

____

____

How do you plan to protect the buggy inside the Landing Pod?

____

____

____

What will you use to protect the outside of the Landing Pod?

____

____

____

How will you make sure the Landing Pod lands on the surface in the Buggy's correct orientation?

____

____

____

Draw your Landing Pod.

Outside view with door or "hatch"
Inside view with Buggy placement ***Approved By ________________***

EXPERIMENT AND RECORD

Perform several drop tests of various heights with your Landing Pod. Start with a height less than the height being used for the actual lunar landing (height mentioned by teacher). Note carefully how it lands and think about what changes need to be made to improve the landing.

Landing Pod Drop Test Data Table

Trial	Drop Height (m)	Observations
1		
2		
3		

What is the most difficult constraint to satisfy in your Landing Pod?

____

____

List the design changes made to your Landing Pod between trials.

____

____

Now for the actual lunar landing! Follow your teacher's instructions, then answer the following questions.

Post Lunar Landing

Did the Landing Pod remain closed during impact? (YES or NO)	Did the Lunar Buggy land in an upright position? (YES or NO)	How far did the Buggy roll beyond the ramp? (cm)

QUALITY ASSURANCE FORM

Each team is to review another team's design and model, then answer the following questions.

Name of team reviewed: ______________________________

Total mass of the Lunar Rover and Landing Pod is: _____ grams

Did the Landing Pod land upright when dropped from a height of ______ meters?

List specific strengths of the design.

List specific weaknesses of the design:

How would you improve the design?

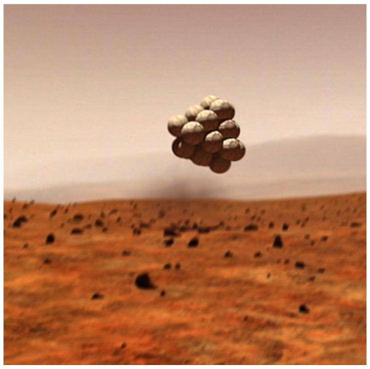
Inspected by: ___________________________________

____

____

____

FUN WITH ENGINEERING AT HOME



Today you simulated the landing of your Lunar Buggy on the Moon. This activity models the way the Mars Exploration Rovers landed on the surface of Mars. Tell your family about how your Landing Pod survived the stress of impact. What were its strong points? If you could design it again, would you do anything differently? Ask family members if they have any ideas on how to improve the Landing Pod your team designed.

Mars is not the only planet NASA has visited through robotics. Do a little research with your family members to answer these questions:

1. NASA has also dropped satellites into the atmospheres of Venus and Jupiter. What happened to those spacecrafts?
2. When humans landed on the Moon, what kind of a vehicle did they use? How was this vehicle slowed down to prevent a catastrophic impact on the surface?

CHALLENGE YOURSELF!

Write a one-page letter to the NASA engineers working on lunar exploration telling them of your suggestions for building a Landing Pod that will deliver its payload safely to the surface.

DESIGN A CREW EXPLORATION VEHICLE

OBJECTIVE

To demonstrate an understanding of the Engineering Design Process while utilizing each stage to successfully complete a team challenge.

CHALLENGE

To design and build a Crew Exploration Vehicle (CEV) that will carry two - 2 cm sized passengers safely and will fit within a certain volume (size limitation). The CEV will be launched in the next session.

PROCESS SKILLS

Measuring, calculating, designing, evaluating.

MATERIALS

General building supplies

Digital scale

Mailing tube, oatmeal canister, or small coffee can (used as size constraint)

2 - 2 cm plastic people (i.e. Lego®)

STUDENT PAGES

Design Challenge

Ask, Imagine and Plan

Experiment and Record

Quality Assurance Form

Fun with Engineering at Home

PRE ACTIVITY SETUP

Select a size constraint (mailing tube, oatmeal canister or coffee can). Fill in the sentence on the Design Challenge so students will know what the size constraint is for their CEV.

MOTIVATE

- Show the NASA BEST video titled "Repeatability":

  svs.gsfc.nasa.gov/goto?10515

- Ask the students why it is important to test their own designs.

SET THE STAGE, ASK, IMAGINE, PLAN

- Share the *Design Challenge* with the students.
- Remind students to imagine a solution and draw their ideas. All drawings should be approved before building.

CREATE

- Challenge students to build their CEVs based on their designs. Remind them to keep within specifications.
- Visit each team and test their designs to ensure they fit within the size specifications of the cylinder you are using.

EXPERIMENT

- Each team must conduct three drop test (at 1, 2 and 3 m) and record the results.

IMPROVE

- After each drop test, the students *improve* CEV models based on the results of the experiment.

CHALLENGE CLOSURE

Engage the students with the following questions:

- *What was the greatest challenge for your team today?*
- *Why was it important that the hatch stay closed during the drop tests?*
- *What process will your CEV undergo that makes it important for the astronauts to stay secured in their seats?*

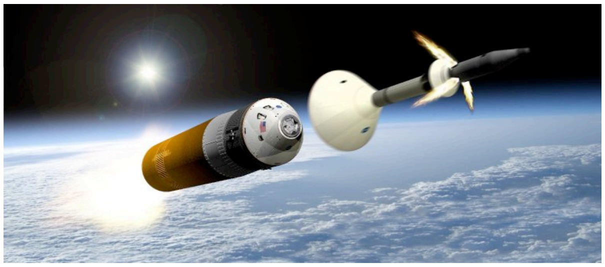
PREVIEWING NEXT SESSION

Ask teams to bring back their CEV model for use in next session's challenge. You may want to store them in the classroom or have one of the facilitators be responsible for their safe return next session.

Ask teams to think about potential launch mechanisms before the next session. Tell them they will be building a launcher out of the standard materials that have been available to them, including large rubber bands.

DESIGN CHALLENGE

Taking humans back to the Moon…40 years later!



NASA needs a new vehicle to take astronauts to the Moon because the Space Shuttle was never designed to leave the Earth's orbit. NASA and its industry partners are working on a space vehicle that will take astronauts to the Moon, Mars, and beyond. This spacecraft is called the Crew Exploration Vehicle (CEV). The CEV is a vehicle to transport human crews beyond low-Earth orbit and back again. The CEV must be designed to serve multiple functions and operate in a variety of environments.

The Challenge: *Each team must design and build a Crew Exploration Vehicle with the following constraints:*

1. *The CEV must safely carry two "astronauts". You must design and build a secure seat for these astronauts, without gluing or taping them in place. The astronauts should stay in their seats during each drop test.*
2. *The CEV must* ***fit within the _______________****. This item serves simply as a size constraint. The CEV is not to be stored in this or launched from this item.*
3. *The CEV must include a model of an internal holding tank for fuel with a volume of 30 cm^3. (Note: your tanks will not actually be filled with a liquid.)*
4. *The total mass cannot exceed 100 grams. Use a scale or balance to measure the mass of your design components.*
5. *The CEV must have one hatch that opens and closes and is a size that your "astronauts" can easily enter/exit from. The hatch should remain shut during all drop tests.*

ASK, IMAGINE AND PLAN

What questions do you have about today's challenge?

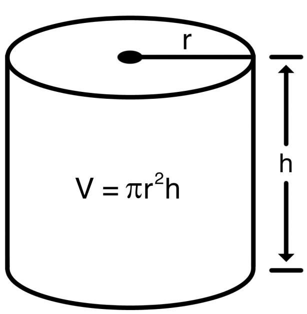
Draw your Crew Exploration Vehicle (CEV) and show a view with the hatch. Also include an inside look (cutaway view) at where your astronauts sit and where the internal tank is positioned.

Approved By _______________

CEV Characteristics Data Table

Vehicle components	Use	Measurement or Calculation
Astronauts	Crew	Mass: ________________ grams each ________________ grams total
CEV	Carries crew to Moon	Mass: ________________ grams
Hatch	Allows entry and exit	Dimensions: ________________ cm (long) by ________________ cm (wide)
Internal Tank	Stores liquid fuel	Mass: ________________ grams Volume: ________________ cm^3
Mailing Tube	To test size constraint	Volume: ________________ cm^3

HINT – How to calculate the volume of a cylinder:



1. Find the radius of the circle found at the top and bottom of the cylinder. The radius (r) is half of the measurement of the diameter of the circle.
2. Square the radius value and multiply it by π (pi).
3. Determine the height (h) of your cylinder and multiply it by the value found in step #2.

EXPERIMENT AND RECORD

Drop your CEV model from three different heights: 1 meter, 2 meters and 3 meters. The drop height is the *independent variable* of this experiment. Record a *dependent variable* from each drop, noting the results of the drop. For example, the number of astronauts that stayed in their seats during the drop is a dependent variable because its results are *dependent* upon the height of the drop.

CEV Drop Test Data Table

Independent Variable Drop Height	Dependent variable(s)
1 meter	
2 meters	
3 meters	

What was the most difficult constraint to satisfy in your CEV?

____

____

List the design changes made to your CEV between trials.

____

____

____

QUALITY ASSURANCE FORM

Each team is to review another team's design and model, then answer the following questions.

Name of team reviewed: ______________________________

Total mass of the Crew Exploration Vehicle is: ________ grams

Does the CEV fit within specified dimensions?

Does the hatch open and close?

Did the astronauts stay in their seats during the drop tests?

List specific strengths of the design:

List specific weaknesses of the design:

How would you improve the design?

Inspected by: ___________________________________

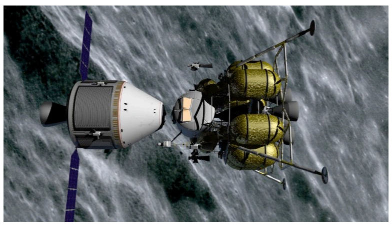
____

____

____

FUN WITH ENGINEERING AT HOME

Today you designed and built a Crew Exploration Vehicle (CEV) model to carry astronauts to the Moon. While at home, see what you can learn about satellites and rockets that are launched into orbit. Next session, you will be designing a launcher for the Crew Exploration Vehicle. It will be important to test launch the CEV several times so that in the future we may send humans SAFELY into space.



YOU BE THE TEACHER!

Sending humans back to the Moon is a highly debated subject amongst leading scientists, engineers, politicians and the public. Try hosting a family discussion about this topic. Use these questions as a guide:

1. *Do you believe we should send humans back to the Moon? Why or why not?*
2. *Would you want to go to the Moon?*
3. *What might be some of the dangers for humans in a new CEV?*
4. *What is the most dangerous part of the journey to Mars?*

LAUNCH YOUR CEV

OBJECTIVE

To demonstrate an understanding of the Engineering Design Process while utilizing each stage to successfully complete a team challenge.

CHALLENGE

To design and test a Reusable Launcher for the Crew Exploration Vehicle (CEV). The CEV should travel 5 meters when launched.

PROCESS SKILLS

Measuring, calculating, designing, evaluating.

MATERIALS

Model CEV that was built last session

General building supplies

Meter stick or measuring tape

C-clamps

Rubber bands of various sizes

STUDENT PAGES

Design Challenge

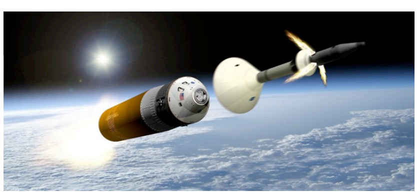
Ask, Imagine and Plan

Experiment and Record

Quality Assurance Form

Fun with Engineering at Home

PRE ACTIVITY SET UP - See next page.



MOTIVATE

- Show the first two minutes of the video titled "Constellation: Flight Tests". (if time permits, show all)

www.nasa.gov/mission_pages/constellation/multimedia/index.html

- Ask the students what was the most important lesson learned from those images? (test, test and test again!)

SET THE STAGE, ASK, IMAGINE, PLAN

- Share the *Design Challenge* with the students.
- Emphasize that the objective is to create a launcher producing repeatable results. It is more important for the CEV to reach the same distance each time than for the CEV to travel the farthest.
- Remind students to imagine a solution and draw their ideas. All drawings should be approved before building.

CREATE

- Challenge the students to build a Reusable Launcher based on their designs and ideas.

EXPERIMENT

- Students will test different rubber bands and different distances the rubber band is pulled back. One rubber band is used per experiment, but tested at three different "pull lengths". All data is recorded in the data table.
- Students should graph the CEV distance results as a line graph and analyze. *Feel free to share the BEST graphing video with your students as a refresher on how to build a graph: svs.gsfc.nasa.gov/goto?10515.*

IMPROVE

- Students *improve* the Reusable Launcher based on results of the tests.

CHALLENGE CLOSURE

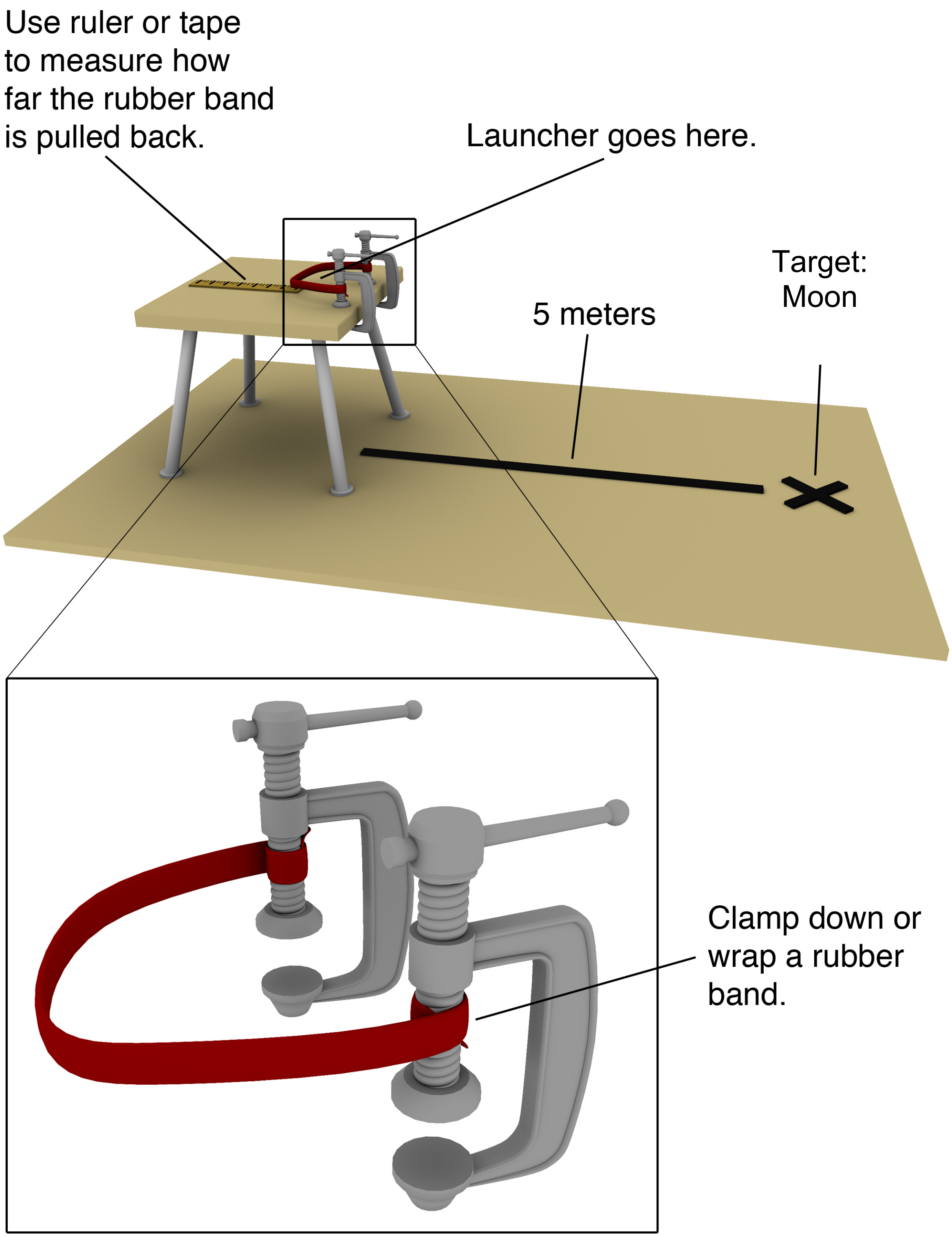
Engage the students with the following questions:

- *Why was it important that the launcher be reusable?*
- *Why was it important that your results were repeatable?*

PREVIEWING NEXT SET OF ACTIVITIES (SERIES 3)

The Moon is a very harsh environment. There is no atmosphere to protect astronauts and their equipment from solar radiation and the extreme temperature swings between night and day. Next session, we will begin to find ways to protect astronauts from those extreme temperature changes.

LAUNCH SET-UP



It's Time to Launch into Space!

For years, NASA has been reusing launch components to send rockets and the Space Shuttle into space. For example, the solid rocket boosters (SRB's) on the Space Shuttle are often retrieved from the ocean, brought back to Kennedy Space Center, then cleaned and prepped for another Shuttle Launch. Why? The same reason we recycle our aluminum cans. It helps the environment and helps us save money for future launches. During this session, you must design and test a Reusable Launcher for your Crew Exploration Vehicle that will journey to the Moon. Therefore, your goal will be to launch your CEV into an orbit around the Moon.

The Challenge: To design and test a Reusable Launcher with the following constraints:

1. *Launch the CEV to reach a goal of **5 meters**. See the drawing on the previous page for an idea of how to set up your launch.*
2. *The Launcher must be reusable for each trial. If your rubber band breaks because it was pulled too far, it is not reusable for another launch.*
3. *The Launcher must consist of an effective combination of rubber band type and how far back it should be pulled. You will experiment with three types of rubber bands and try three different lengths to pull those rubber bands back (think of a sling shot, but attached to a table).*
4. *The Launcher must produce a repeatable outcome. If you set up the Launcher the same way twice, the CEV should travel the same distance both times. It is more important that the CEV is launched the same distance using the same setup than it is to get the CEV to travel the farthest distance.*

ASK, IMAGINE AND PLAN

What questions do you have about today's challenge?

Describe the characteristics of the three rubber bands your team has chosen to use.

____

____

How will you test your rubber bands to see if they will work well as a "Reusable Launcher"?

____

Draw a picture of your team's Reusable Launcher with your CEV.

Approved By _______________

EXPERIMENT AND RECORD

Choose your three rubber bands and set up the Reusable Launcher for your experiment. Enter the independent variables into the table. Launch your CEV three times for each type of rubber band. Measure the dependent variables – how far your CEV travelled and how much it missed the 5 m target. Record your data.

CEV Launch Data Table

Trial	**Independent Variables**		**Dependent Variables**	
	Type of rubber band (description)	Rubber band pulled length (cm)	Distance traveled (m)	Distance from target (m)
1				
2				
3				
1				
2				
3				
1				
2				
3				

Did you get a repeatable outcome? If not, how will you improve your design to get consistent results?

____

____

____

Use the data recorded to make a line graph to show your results. The x-axis is the *independent variable* and the y-axis is the *dependent variable*. Label each axis with its measured units, and make tick marks on the graph with numbers so that you will be able to plot your data. Plot three sets of data, using a different color for each type of rubber band.

From your graph, can you determine if there is a relationship between the distance the rubber band is pulled and the distance that your CEV traveled? If so, describe that relationship.

QUALITY ASSURANCE FORM

Each team is to review another team's design and model, then answer the following questions.

Name of team reviewed: ______________________________

Did the launcher successfully send the CEV 5 meters out?

If no, what was the distance accomplished by the launcher?

Describe the rubber band that was used in the launcher.

Did the CEV sustain any damages from the launch?

List specific strengths of the design:

List specific weaknesses of the design:

How would you improve the design?

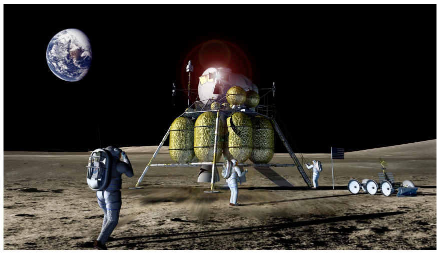
Inspected by: ______________________________

____

____

____

FUN WITH ENGINEERING AT HOME

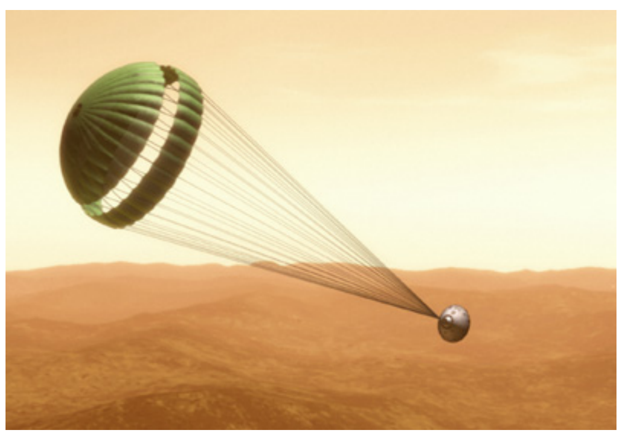


Today you designed and built a Reusable Launcher to launch the CEV model that you built last session. You were designing the Reusable Launcher to get to a certain distance (5 meters). You used the same process that engineers use when they build something. Share with your family this movie and have a discussion about humans returning to the Moon:

www.nasa.gov/mission_pages/constellation/multimedia/index.html

YOU BE THE TEACHER!

Explain to your family why we cannot use a parachute for landing on the Moon.



DESIGN A LUNAR THERMOS

OBJECTIVE

To demonstrate an understanding of Engineering Design Process while utilizing each stage to successfully complete a team challenge.

CHALLENGE

To design an insulator for a cup of hot water and a cup of cold water to maintain water temperature relatively constant. To apply the understanding of how things get warmer and cooler heat transfer.

PROCESS SKILLS

Experimental design, measuring, graphing and data analysis

MATERIALS

Glow sticks (2)

Thermometers

Stopwatches

Graduated cylinders

Plastic cups

Insulating materials (e.g. bubble wrap, paper, cloth, sand, water, foil, Styrofoam, etc)

STUDENT PAGES

Ask, Imagine and Plan

Experiment and Record

Quality Assurance Form

Fun with Engineering at Home

PRE ACTIVITY SETUP

While the students are using the EDP to create an insulator, they will also be conducting a scientific experiment that requires a control. You will need to designate a place where students will get their hot and cold water for this experiment, or prepare the water for them ahead of time. Refresh as needed.

Please note: *This activity may require two 60-90 minute sessions to complete.*

MOTIVATE

- Ever wonder what is involved in designing today's spacesuits? Check out this interactive site to learn about NASA's spacesuits:

  www.nasa.gov/audience/foreducators/spacesuits/home/clickable_suit.html

SET THE STAGE: *ASK, IMAGINE, PLAN*

- Share the *Design Challenge* with the students
- Place a glow stick in a clear cup of hot water and a clear cup of cold water, then turn off the lights. Ask the students to explain the difference between the two sticks and how that might relate to the movement of molecules (which ones move slow, which ones move fast).

CREATE

- Challenge the students to devise an insulation system to keep water at a constant temperature.

EXPERIMENT

- Have students follow the directions on the *Experiment and Record* worksheet to complete their experiment.
- If there are four team members, save time by having two students do the test with the hot water (experiment and control) while the other two students do the test with the cold water (experiment and control).
- Students should graph the temperature results as a line graph and analyze. *Feel free to share the BEST graphing video with your students as a refresher on how to build a graph: svs.gsfc.nasa.gov/goto?10515.*

IMPROVE

- Have students design other combinations of materials to reduce any temperature fluctuation found in their first design.

CHALLENGE CLOSURE

Engage the students in a discussion with the following questions:

- *Does it matter whether the application of keeping my soup warm until lunch is as effective as keeping my body at roughly "body temperature" when on the Moon?*
- *Do you think the temperatures in the cup will reach the same temperature as the air in room? If so, predict how long this would take.*

PREVIEWING NEXT SESSION

During this session, you explored designing insulation to reduce temperature changes, much like protecting humans from the extreme temperature swings on the Moon's surface. What if you needed to capture heat energy instead? Why would you need to capture heat energy if we wanted to live on the Moon?

Oh, to not have an atmosphere!

There is no atmosphere on the Moon, so temperatures fluctuate through a very wide range. In the shadowed areas of the Moon the temperature ranges from as low as −180 °C (or −300 °F), and in the sunlit areas it is about 100 °C (or 212 °F), which is the boiling point for water! These are serious extremes for human beings! Furthermore, there are spots on the Moon that are permanently exposed to the Sun, and others permanently in shadow. It is in the permanently shadowed areas of some craters that scientists believe water ice may exist.

Anyone living on the Moon - even for a short while - will have to deal with this temperature variation and be protected properly from its damaging effects. Just think about the number of layers you wear when going outside on a very cold winter's day. The goal in designing a space suit is to create protective layers to keep a human body at a fairly constant temperature. Therefore, we must understand how heat moves. Engineers need to design protective wear to **prevent heat** from being transferred to, or transferred away, from our bodies. How could we **insulate** ourselves from the wide variations of temperature in the lunar environment?

The Challenge: Your mission is to design a "Lunar Thermos" – a protective insulator for a cup of hot and a cup of cold water. Using your Lunar Thermos design, you will conduct an experiment to compare your insulated cups to unprotected cups (the control). The design constraints are:

1. *Use any combination of materials available to you to create a protective insulating layer to keep a cup of hot water and a cup of cold water at a relatively constant temperatures.*
2. *Your "Thermos" temperature should change by no more than 5 °C over 10 minutes.*
3. *Your team must pre-determine what is optimal for your Lunar Thermos design: (a) volume of water to use in each cup and (b) how hot or how cold the water should be at the beginning of the experiment and (c) the frequency of measuring the temperature in each cup.*
4. *You must be able to graph your results.*

ASK, IMAGINE AND PLAN

What questions do you have about today's challenge?

Today you will conduct an experiment to demonstrate the movement of atoms and molecules through temperature measurements and engineer a design that can slow down that movement. Take a few minutes and find the definitions of these words and phrases:

HEAT____

____

TEMPERATURE____

____

EQUILIBRIUM____

____

THERMAL ENERGY TRANSFER____

____

Before you begin setting up an experiment, can you predict how the temperature will change in each cup? Using the vocabulary from above, write a hypothesis for what you think will happen in the experiment.

____

____

____

Design your experiment:

How much water do you plan to use for each cup (in mL)? ___________________

How often will you check the change in temperature of the water?____________

What materials will you use as insulation? __________________________________

Draw and label your Lunar Thermos.

Approved By _______________

EXPERIMENT AND RECORD

1. Record the temperature of the room: _______________ °C
2. Using a graduated cylinder, collect the cold water and pour it into one plastic cup. Repeat for the hot water.
3. Record the temperature for each cup of water for the times planned earlier and record the results in the **control** column.
4. Now build your Lunar Thermos for each cup and repeat the experiment. Record your results for Trial 1.
5. Improve your design by trying another combination of materials and repeat the experiment. Record your results for Trial 2.

Lunar Thermos Data Table

Time (Min:sec)	Cold Water Cup (°C)			Hot Water Cup (°C)		
	Control	Thermos Trial 1	Thermos Trial 2	Control	Thermos Trial 1	Thermos Trial 2
0:00						

Lunar Thermos Data Table Continued

Time	Control	Trial 1	Trial 2	Control	Trial 1	Trial 2

Create a line graph of your results and indicate where your cups of water may have reached equilibrium. Make sure to label your axes and use different colors or line styles to represent the cold and hot water cups.

TRIAL 1

TRIAL 2

QUALITY ASSURANCE FORM

Each team is to review another team's design and model, then answer the following questions.

Name of team reviewed: ______________________________

	YES	NO
Were the cups properly labeled for the hot and cold water?		
Did the team use enough water to perform the experiment properly?		
Did the team graph the data correctly?		
Did the hot or cold water cup ever reach equilibrium?		

How many times was the temperature measured? ________________

List the specific strengths of the experiment.

List the specific weaknesses of the experiment:

How would you improve the experiment?

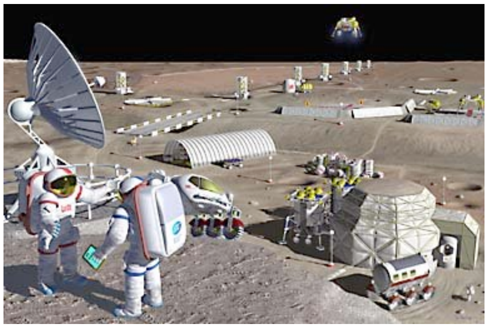
Inspected by: ___________________________________

Signatures: ___________________________________

____

____

FUN WITH ENGINEERING AT HOME



During this session you have learned about the flow of heat and how objects reach thermal equilibrium. You also experimented with a way to slow down that energy transfer. These are all important concepts to understand and implement if humans are to live and work on the Moon or other planet. What would happen if we actually needed to harness solar energy to provide power in a remote location? Talk with your family members about all the ways we could use energy from the Sun to do work for us. Can you think of four methods, man-made or natural?

1.

2.

3.

4.

YOU BE THE TEACHER!

Do you think you can explain the principle of thermal transfer as it applies to boiling water for tea? What happens to the water in the tea kettle when you place it on the stove and turn the heat on?

BUILD A SOLAR OVEN

OBJECTIVE

To demonstrate an understanding of Engineering Design Process while utilizing each stage to successfully complete a team challenge.

CHALLENGE

To design and build a solar box cooker, and test it to see if it works well enough to make S'mores!

PROCESS SKILLS

Experimental design, measuring, graphing and data analysis

MATERIALS

General building supplies

Thermometer

Timers

Cardboard box

Aluminum pans

Aluminum foil

Black construction paper

Plexiglass or plastic wrap big enough to cover the box

Sunshine, OR gooseneck lamp with 100 W bulb

S'mores fixin's (graham crackers, marshmallows and chocolate)

Oven mitts or tongs

STUDENT PAGES

Imagine and Plan

Experiment and Record

Quality Assurance Form

Fun with Engineering at Home

PRE ACTIVITY SETUP

It is recommended to take a few minutes at the start of the session to discuss safe handling procedures of the food and of their solar ovens when exposed to the sun: (1) Remind students the importance of hand washing before handling food; and (2) Ovens will get hot and will require the use of protective gear or a tool to manipulate items in and out of the ovens.

Please note: *This activity may require two 60-90 minute sessions to complete.*

MOTIVATE

- Have students watch the video "Living on the Moon":

  http://svs.gsfc.nasa.gov/goto?10515

SET THE STAGE: *ASK, IMAGINE, PLAN*

- Share the *Design Challenge* with the students
- Remind students to imagine a solution and draw their ideas. All drawings should be approved before building.
- Tell students that if they succeed in their design, a tasty treat will be had!

CREATE

- Hand out the materials to the students and challenge them to build their own solar ovens.

EXPERIMENT

- Have students follow the directions on the *Experiment and Record* worksheet to complete their experiment.
- Once the oven is built, students should place a S'more and the thermometer in the box and cover with plastic wrap or plexiglass lid.
- Place the box in direct sunlight (students may have to tilt the box so that there are no shadows inside). If it is a cloudy day, use a goose neck lamp with the 100 W bulb.
- Ensure students use oven mitts when moving the plexiglass lid or removing items from the solar oven once exposed to the sun.

IMPROVE

- If there is time, have students inspect their designs and the experiment results. Allow teams to rework their designs if needed.

CHALLENGE CLOSURE

Engage the students with the following questions:

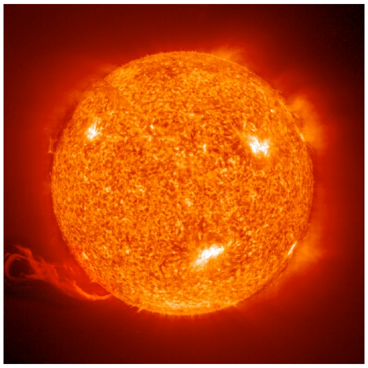
- *Whose oven reached the highest temperature? What was that temperature? Did it melt the marshmallows and the chocolate?*
- *What could you have done to make your solar oven work better?*
- *Does it make a difference using actual sunlight compared to light from a lamp? Why or why not?*
- *How did the distances from the bottom reflective surface affect the cooking of the food in your oven?*

END OF PROGRAM

This session concludes the NASA's Beginning, Engineering, Science and Technology series. Students now should have a firm grasp of the Engineering Design Process and how it is applied in real applications of our quest to travel to the Moon, Mars and beyond. Print out a certificate for each student for completing all the steps to becoming a NASA's BEST student (see end of guide).

DESIGN CHALLENGE

Can we cook while on the Moon?



While astronauts might have to bring just about everything with them when we establish a habitat on the Moon, one thing they won't need is solar energy. There may be no atmosphere, no climate nor weather on the Moon, but that DOES make it an ideal place to collect solar energy. Much of the Moon is exposed to sunlight constantly, except briefly during a rare lunar eclipse. If that energy could be harnessed, it could power almost everything in the lunar habitat…including that most important device that helps prepare delicious food – an oven!

The Challenge: Your mission is to design and build a solar oven to cook your own S'mores with the materials provided. Your design constraints are:

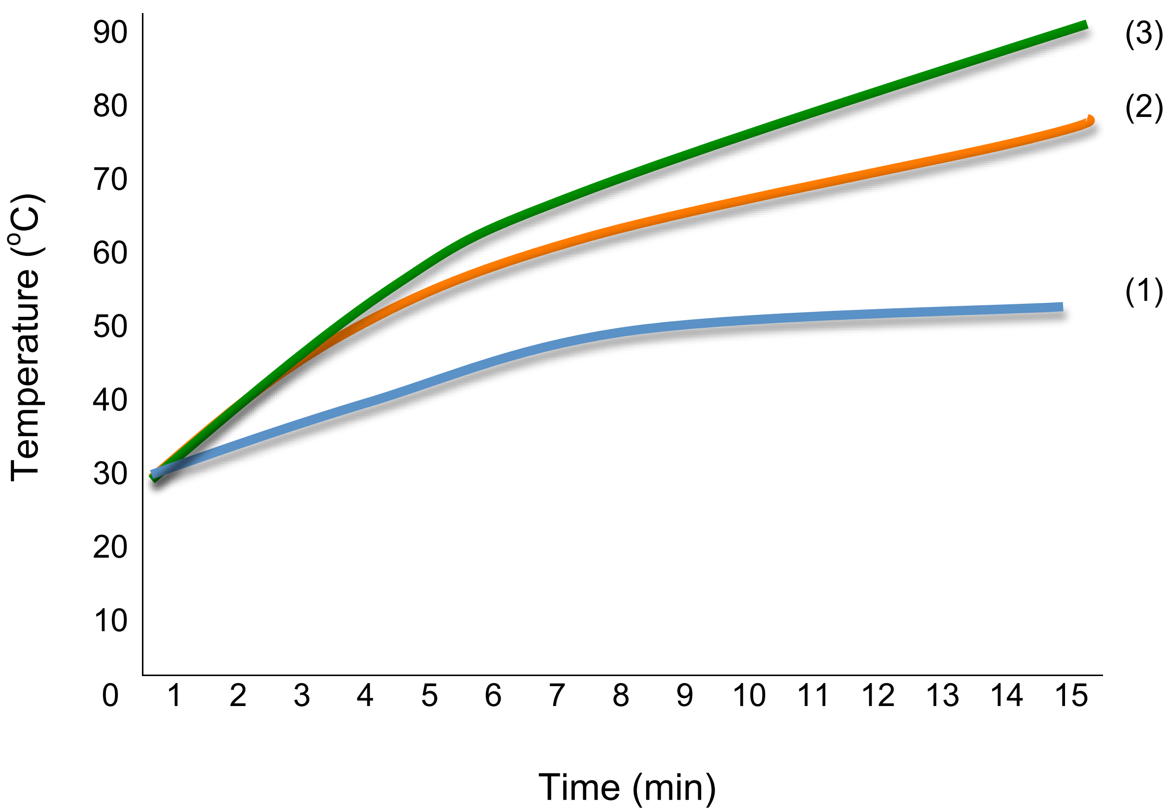
1. *The oven must have a "footprint" of no more than 40 cm x 40 cm.*
2. *In 10 minutes, the temperature inside the oven must increase by 15 °C.*
3. *Your food may not touch the bottom of the oven directly. You must design an effective way to cook the two S'mores without their touching of the oven bottom.*
4. *You must cook the two S'mores at two different heights. You will also test which height allows food to cook at a faster rate.*

SAFETY NOTE: Contents of solar oven can get very hot. Make sure you use oven mitts or other protective wear when manipulating anything inside of your oven!

ASK, IMAGINE AND PLAN

What questions do you have about today's challenge?

Below is a graph showing data that demonstrates the efficiency of three different solar oven designs: (1) plain box, (2) box with a black bottom and (3) a box with aluminum foil and a black bottom.



Which line (1, 2 or 3) do you think represents the solar oven that is just an empty box? Explain why.

____

Which line do you think represents the solar oven with aluminum foil and a black bottom? Explain why.

____

What purpose do you think aluminum foil might serve?

____

How will you meet the design constraint of the food not being allowed to touch the bottom surface of the solar oven?

____

Draw and label your solar oven.

Approved By _______________

EXPERIMENT AND RECORD

1. Using the materials provided, build you solar oven based on your design. Remember the goal is to *capture* heat in your oven.
2. Record the starting temperature of the oven: __________________ °C
3. Record the heights of the food from the oven floor: ______ cm ______ cm
4. Prepare your S'mores and place them in the oven. Cover the oven with the plexiglass lid or plastic wrap and begin cooking.
5. Record the temperature change in the table below.

Solar Oven Data Table

Time Min:sec	Oven Temperature °C	Time Min:sec	Oven Temperature °C
0:00		5:30	
0:30		6:00	
1:00		6:30	
1:30		7:00	
2:00		7:30	
2:30		8:00	
3:00		8:30	
3:30		9:00	
4:00		9:30	
4:30		10:00	
5:00		10:30	

Record any observations of your food while it is cooking. These observations will help to determine which food placement height allows for quicker cooking.

Solar Oven Food Observations

Time Min:sec	S'more 1 ______ cm	S'more 2 ______ cm
1:00		
2:00		
3:00		
4:00		
5:00		
6:00		
7:00		
8:00		
9:00		
10:00		

QUALITY ASSURANCE FORM

Each team is to review another team's design and model, then answer the following questions.

Name of team reviewed: ______________________________

	YES	NO
Did the solar oven increase in temperature by more than 10ºC?		
Did this team's design differ from your team's design?		
Did both S'mores melt?		

Which height/cooking position worked best in this solar oven?

List the specific strengths of the design:

List the specific weaknesses of the design:

How would you improve the design?

Inspected by: ___________________________________

Signatures: ___________________________________

____

____

FUN WITH ENGINEERING AT HOME

Today you learned a fun way to harness the Sun's energy, trapping the radiant heat from the Sun to cook food. With your family members, look up the meaning of "the greenhouse effect". Can you explain what "the greenhouse effect" has to do with the solar oven your team designed and built?

Discuss with your family members the following question:

Why do we use the term "the greenhouse effect" when talking about global warming?

YOU BE THE TEACHER!

Show your family how to build a solar oven. Test it out by cooking something new. How about baking a pizza in your solar oven? Grab a frozen pizza from the store or make one from scratch. Use the results of your experiment to determine at what height to place your pizza in the oven.

This marks the end to the NASA Beginning Engineering, Science and Technology (BEST) series. We encourage you to continue to look for more activities, articles and podcasts about NASA any day and every day!

www.nasa.gov

ALIGNMENT TO NATIONAL STANDARDS

SCIENCE

	6	7	8
Science as Inquiry			
Develop abilities necessary to do scientific inquiry.	✓	✓	✓
Develop understanding about scientific inquiry.	✓	✓	✓
Develop understanding of objects in the sky.	✓	✓	✓
Science and Technology			
Develop abilities to do technological design.	✓	✓	✓
Develop understanding about science and technology.	✓	✓	✓
History of Nature and Science			
Develop understanding of science as a human endeavor.	✓	✓	✓
Physical Science			
Motions and forces	✓		✓
Transfer of energy			✓

TECHNOLOGY & ENGINEERING

Creativity and Innovation			
Apply existing knowledge to generate new ideas, products or processes.	✓	✓	✓
Create original works as a means of personal or group expression.	✓	✓	✓
Use models and simulations to explore complex systems and issues.	✓	✓	✓
Research and Information Fluency			
Locate, organize, analyze, evaluate, synthesize and ethically use information from a variety of sources and media.			✓
Evaluate and select information sources and digital tools based on the appropriateness to specific tasks.			✓
Critical Thinking, Problem Solving, and Decision Making			
Identify and define authentic problems and significant questions for investigation.	✓	✓	✓
Digital Citizenship			
Exhibit a positive attitude toward using technology that supports collaboration, learning and productivity.	✓	✓	✓

MATHEMATICS

	6	7	8
Numbers and Operations			
Compute fluently and make reasonable estimates.	✓	✓	✓
Measurement			
Understand measureable attributes of objects and the units, systems, and processes of measurement.	✓	✓	✓
Understand, select and use units of appropriate size and type to measure angles, perimeter, area, surface area, mass, temperature and volume.	✓	✓	✓
Solve problems involving scale factors, using ratio and proportion.	✓	✓	✓
Data Analysis and Probability			
Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.	✓	✓	✓
Select and use appropriate statistical methods to analyze data.	✓	✓	✓
Develop and evaluate inferences and predictions that are based on data.	✓	✓	✓
Problem Solving			
Build new mathematical knowledge through problem solving.	✓	✓	✓
Solve problems that arise in mathematical and in other contexts.	✓	✓	✓
Apply and adapt a variety of appropriate strategies to solve problems.	✓	✓	✓
Algebra			
Use mathematical models to represent and understand quantitative relationships.	✓	✓	✓
Analyze change in various contexts.	✓	✓	✓
Communication			
Communicate mathematical thinking coherently and clearly to peers, teachers and others.	✓	✓	✓
Analyze and evaluate the mathematical thinking and strategies of others.	✓	✓	✓
Use the language of mathematics to express mathematical ideas precisely.	✓	✓	✓

ORIGINAL ACTIVITY SOURCES

Launch Your Satellite adapted from **Rockets Educator Guide:**

www.nasa.gov/pdf/58269main_Rockets.Guide.pdf

Prepare for a Mission adapted from **Principles of Remote Exploration** at:

learners.gsfc.nasa.gov/PREP/

Design the new Crew Exploration Vehicle! adapted from **NASA's KSNN™ 21st Century Explorer newsbreak "What will replace the space shuttle?"** at*:*

education.jsc.nasa.gov/explorers/pdf/p5_educator.pdf

Build a Solar Oven adapted from **Lunar Nautics***, but is also a very popular activity found in many science textbooks:*
www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Lunar_Nautics_Designing_a_Mission.html

RECOMMENDED BOOKS AND VIDEOS

Need a little background information about the Moon, NASA History or earlier space exploration missions? Below is a suggested library list to help prepare you to provide answers to your students, or material to share with or recommend to your students to explore further. We thank our friends at St. Michael School in Hudson, MA for compiling this comprehensive list.

Adamson, Thomas K. **First Moon Landing**. Mankato, Minn: Capstone, 2007. Print. *The story of the first landing of men on the Moon in July of 1969. Picture book.*

Aguilar, David A. **11 Planets: A New View of the Solar System**. Washington DC: National Geographic, 2008. Print. *Provides an introduction to the planets of the solar system, including the two new dwarf planets, Ceres and Eris.*

Aldrin, Buzz. **Reaching for the Moon**. New York: Harper Collins, 2005. Print. *An Apollo 11 astronaut takes readers on his journey that began in his childhood and led him to achieve his dream of walking on the Moon, bringing to life an unparalleled moment in history for a new generation and showing how everyone can strive to achieve their dreams.*

AstroPuppies in Space. Dir. Tim Tully. 2009. Universe Productions, 2009. DVD. *Dramatic NASA videos and stunning photos from the Hubble Space Telescope are blended with puppetry and instructive animations, songs, and poems. This is an entertaining and educational introduction to astronomy and space exploration for young children.* (Amazon)

Bell, Jim. **Mars 3-D: A Rover's-Eye View of the Red Planet**. New York: Sterling, 2009. Print. *Presents the harsh landscape of the Red Planet through 3-D and color images from the robotic explorers Spirit and Opportunity; provides a close-up look at the Martian rocks, craters, valleys, and other geologic configurations.*

Bennett, Jeffrey. **Max Goes to Mars: A Science Adventure With Max the Dog.** Boulder, Colorado: Big Kid Science, 2006. Print. *When Max the dog becomes the first canine to embark on a mission to Mars, he makes one of the most important discoveries of all time, in a book that includes facts about Mars.*

Bennett, Jeffrey. **Max Goes to the Moon: A Science Adventure With Max the Dog.** Boulder, Colorado: Big Kid Science, 2003. Print. *Taking the first trip to the Moon since the Apollo missions, Max the dog and his friend Tori help set up the first colony on the Moon.*

Bunting, Eve. **My Robot**. Orlando, FL: Harcourt, 2006. Print. *Cecil the robot is good at playing tag, leading the school band, and performing tricks with the dog, but there is one important thing he does best of all.*

Chaikin, Andrew. **Voices from the Moon: Apollo Astronauts Describe Their Lunar Experiences.** New York: Viking, 2009. Print. *Provides recollections from Apollo astronauts and a collection of photographs that document the history of the Apollo space program.*

Chaikin, Andrew, Victoria Kohl, and Alan Bean. **Mission Control, This Is Apollo: The Story of the First Voyages to the Moon.** New York: Penguin Group, 2009. Print. *Discusses the historic moment in 1969 when Apollo 11 landed on the Moon, the major events that led up to this mission, and the advancements that have been made in space exploration from the Mercury missions to the present day.*

Cobb, Vicki. **I Fall Down.** New York: Harper Collins, 2004. Print. *Hands-on experimentation and fun facts provide beginning readers with a simple introduction to the concept of gravity in terms of how it works, why it works, and its importance in our everyday lives.*

Crelin, Bob. **Faces of the Moon**. Watertown, MA: Charlesbridge, 2009. Print. *Describes the Moon's phases as it orbits the Earth every 29 days using rhyming text and cut-outs that illustrate each phase.*

Dahl, Michael. **On the Launch Pad : A Counting Book About Rockets.** Minneapolis, Minn.: Picture Window Books, 2004. Print. *A countdown from twelve to one as a space shuttle awaits liftoff.*

Dean, James, et al. **NASA/Art: 50 Years of Exploration.** New York: Abrams: In association with NASA and the Smithsonian Institution, 2008. Print. *Ranging from the establishment of NASA in 1958 to the present day, the history of space exploration is chronicled through the work of some of the world's most renowned artists, including Robert Rauschenberg, Andy Warhol, Norman Rockwell, James Wyeth, Alexander Calder, Nam June Paik, William Wegman, and Annie Leibovitz, among others.*

Floca,Brian. **Moonshot: The Flight of Apollo 11**. New York: Atheneum Books for Young Readers, 2008. Print. *From putting on their special uniforms and strapping themselves down in their seats to shooting off into the sky and floating about in space, this informative picture book provides an up-close look at this historic mission to the Moon that took place forty years ago.*

Glatzer, Jenna. **Exploration of the Moon: How American Astronauts Traveled 240,000 Miles to the Moon and Back, and the Fascinating Things They Found There.** Philadelphia: Mason Crest Pub., 2003. Print. *Discusses the Apollo space program of the 1960s and later unmanned NASA probes of the Moon and describes the effects of space flight on the astronauts and some of what has been learned about the moon.*

"The Great Robot Race: The DARPA Grand Challenge." NOVA. PBS. WGBH, Boston, 18 Mar. 2006. Television. *This Nova episode shows the real race of driverless vehicles crossing 130 miles of the Mojave Desert.*

Henderson, Harry. **Modern Robotics : Building Versatile Machines**. New York: Chelsea House, 2006. Print. *Profiles eleven individuals, including mathematicians, engineers, and inventors, who have greatly influenced the field of robotics, focusing on their struggle to accomplish what they have.*

Hyland, Tony. **How Robots Work.** North Mankato, Minn.: Smart Apple Media, 2008. Print. *Describes the kinds of jobs that robots are programmed to do and explains how they work, including how they move, sense the outside world, express feelings, and solve problems.*

"In the Shadow of the Moon." Dir. Ron Howard. 11-7-07. Lionsgate Entertainment, 02-22-08. DVD. *IN THE SHADOW OF THE MOON is an intimate epic, which vividly communicates the daring and the danger, the pride and the passion, of this extraordinary era in American history. Between 1968 and 1972, the world watched in awe each time an American spacecraft voyaged to the Moon. Only 12 American men walked upon its surface and they remain the only human beings to have stood on another world. IN THE SHADOW OF THE MOON combines archival material from the original NASA film footage, much of it never before seen, with interviews with the surviving astronauts, including Jim Lovell (Apollo 8 and 13), Dave Scott (Apollo 9 and 15), John Young (Apollo 10 and 16), Gene Cernan (Apollo 10 and 17), Mike Collins (Apollo 11), Buzz Aldrin (Apollo 11), Alan Bean (Apollo 12), Edgar Mitchell (Apollo 14), Charlie Duke (Apollo 16) and Harrison Schmitt (Apollo 17). The astronauts emerge as eloquent, witty, emotional and very human* (Amazon)

"Is There Life on Mars?." NOVA. PBS. WGBH, Boston, 30 Nov. 2008. Television. *Four years after they landed on Mars, NASA s twin robot explorers, Spirit and Opportunity, have lasted 16 times longer and driven 20 times farther than expected. Today they are joined by an aerial armada of hi-tech satellites, surveying Mars from orbit to reconstruct the planet's mysterious history. And on May 25, 2008, they also got company on the ground: NASA's Phoenix probe. NOVA s Is There Life on Mars? showcases the latest scientific revelations from a planet, once alien, now poised to reveal provocative new clues in the tantalizing quest to plumb its past for signs of water and, perhaps, even life.* (Amazon)

Jedicke, Peter. **Great Moments in Space Exploration.** New York: Chelsea House, 2007. Print. *Describes the steps taken in the history of space exploration, from the development of rockets and satellites to manned space flight and robot rovers.*

Jefferis, David. **Space Probes: Exploring Beyond Earth**. New York: Crabtree, 2009. Print. *Introduces space probes and explains how they monitor the planets and other bodies in the solar system.*

Kerley, Barbara. **Greetings from Planet Earth**. New York: Scholastic, 2007. Print. Set in 1977, *Theo is inspired to do a class project based on space exploration and life on Earth, thusleading him to think about his own life, the mystery surrounding his father in Vietnam, and possibly painful family secrets held by his mother.*

Marino, Nan. **Neil Armstrong Is My Uncle & Other Lies Muscle Man McGinty Told Me.** New York: Roaring Brook Press, 2009. Print. *Tamara dreams of the day when ten-year-old Muscle Man McGinty's constant lies catch up to him, but when an incredible event takes place in the summer of 1969, her outlook on life is altered in the most surprising way.*

McCarthy, Meghan. **Astronaut Handbook.** New York: Knopf, 2008. Print. *Journey aboard the "Vomit Comet" where the students of an astronaut school learn what it is like to do this exciting job by experiencing weightlessness, getting their measurements taken for a space suit, and performing a space walk!*

Moon Machines. Science Channel: A Discovery Company. 16 June 2008. Television. *The right tools for the job... The U.S. Moon missions would never have gotten 10 feet off the ground without the pioneering engineers and manufacturers and the amazing machines they created to turn science fiction into history-making headlines. From nuts and bolts to rockets and life support systems, every piece of gear was custom made from scratch to perform cutting-edge scientific tasks while withstanding the violent rigors of space travel. Now here's your chance to climb aboard the capsule, put on a spacesuit and learn the real stories behind the right stuff.* (Amazon)

Piddock, Charles. **Future Tech: From Personal Robots to Motorized Monocycles**. Washington DC: National Geographic, 2009. Print. *Explores the latest advances in technology and looks at future developments in robotics, medicine, transportation, and family life.*

Platt, Richard, and David Hawcock. **Moon Landing.** Somerville, MA: Candlewick Press, 2008. Print. *A pop-up celebration of Moon exploration recreates the excitement of humankind's dreams of traveling to the Moon, the race to conquer space, the technology needed to reach the Moon and sustain the astronauts in space, and the first Moon landing itself.*

Potter, Frank, and Christopher P Jargodzki, **Mad About Modern Physics: Braintwisters, Paradoxes, and Curiosities**. Hoboken, NJ: J Wiley, 2005. Print.

Prochnow, Dave. **101 Outer Space Projects for the Evil Genius**. New York: McGraw-Hill, 2007. Print. *Describes projects, from model rockets and telescopes to star maps and home planetariums, related to the field of astronomy.*

Pyle, Rod. **Destination Moon: The Apollo Missions in the Astronauts' Own Words.** New York: Harper Collins, 2005. Print. *Encompassing the firsthand accounts of the astronauts and other participants, a complete history of NASA's Apollo program includes coverage of the Apollo 11 Moon landing and the near-catastrophic Apollo 13 mission.*

Rinard, Judith. **Book of Flight: The Smithsonian National Air and Space Museum.** Buffalo, NY: Firefly Books, 2007. Print. *The major milestones in flight history illustrated from the collections of the National Air and Space Museum. Includes the development of flight and diagrams explaining flight science and technology*.

Siy, Alexandra. **Cars on Mars: Roving the Red Planet**. Watertown, MA: Charlesbridge, 2009. Print. *Presents an introduction to the Mars Exploration Rovers (MERS), "Spirit" and "Opportunity," with photographs of the Mars landscape taken over a five-year period as the rovers searched for water on the red planet.*

Stone, Jerry. **One Small Step: Celebrating the First Men on the Moon.** New York: Henry Holt, 2009. Print. *A celebration of the fortieth anniversary of the Apollo 11 Moon landing is a collection of keepsakes and memories that bring America's historic moment of pride and accomplishment to life for a new generation.*

Stone, Tanya Lee. **Almost Astronauts: 13 Women Who Dared To Dream.** Somerville, MA: Candlewick Press, 2009. Print. *Presents the story of the thirteen women connected with NASA's Mercury 13 space mission, who braved prejudice and jealousy to make their mark and open the door for the female pilots and space commanders that would soon follow.*

Thimmesh, Catherine. **Team Moon : How 400,000 People Landed Apollo 11 on the Moon.** Boston: Houghton Mifflin, 2006. Print. *From the engineers to the suit testers, the story of the many people in various professions who worked behind-the-scenes to get Apollo 11 on the Moon and safely back is presented through quotes, transcripts, national archives, and NASA photos.*

Tiner, John Hudson. **100 Scientists Who Shaped World History.** San Mateo, CA: Bluewood Books, 2000. Print. *Profiles the scientists who made significant contributions, describes their failures and accomplishments, and explains how they impacted science and society.*

Todd, Traci. **A Is for Astronaut: Exploring Space from A to Z**. San Francisco: Chronicle Books, 2006. Print. *Provides simple information about space arranged in alphabetical order with vintage and contemporary photographs, including pictures of Ham, the first chimpanzee in space and Neil Armstrong, the first astronaut to walk on the Moon.*

VanCleave, Janice Pratt. **Engineering for Every Kid: Easy Activities That Make Learning Science Fun**. San Francisco: Jossey-Bass, 2006. Print. *Explains some of the basic physical principles of engineering, accompanied by activities that illustrate those principles.*

Van Der Linden, F. Robert. **Best of the National Air and Space Museum.** New York: Harper Collins, 2006. Print. *A photographic tour of some of the top displays from the National Air and Space Museum is complemented by information on each item's history, design, and purpose.*

When We Left Earth. Discovery. June 2008. Television. *Since the dawn of mankind, we have stared up at the lights in the sky and wondered... Now join the heroic men and women who have dared the impossible on some of the greatest adventures ever undertaken - the quest to reach out beyond Earth and into the great unknown of space! To celebrate 50 years of incredible achievements, the Discovery Channel has partnered with NASA to reveal the epic struggles, tragedies and triumphs in a bold chapter of human history. Along with the candid interviews of the people who made it happen, hundreds of hours of never-before-seen film footage from the NASA archives - including sequences on board the actual spacecraft in flight - have been carefully restored, edited and compiled for this landmark collection.* (Amazon)

- - -. **Robots at Work and Play**. North Mankato, Minn: Smart Apple Media, 2008. Print. *Describes how robots can be used to perform work and provide entertainment*.

- - -. **Space Robots**. North Mankato, Minn.: Smart Apple Media, 2008. Print. *Describes how robots have been and will be used to explore the Moon, Mars, and other planets and how they can be used to assist humans during manned missions into space.*

- - -. **Moon 3-d : The Lunar Surface Come to Life**. New York: Sterling, 2009. Print. *Presents a history of the exploration of the Moon along with a collection of 3-D images that can be seen with the provided special glasses.*

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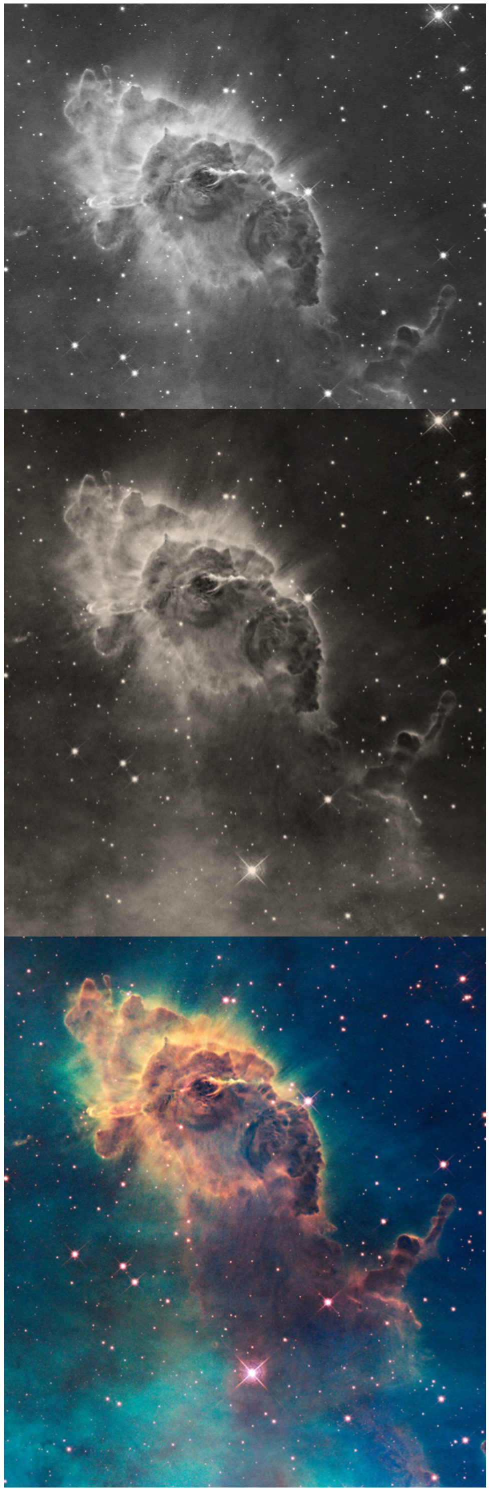

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